Studienzeiten

Themen unserer Zeit

Facharbeiten verfasst durch

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Unter der Leitung von

Noëlle S. M. Nowack

VORWORT

Liebe Leserinnen und Leser,

in dieser Sammlung präsentieren wir die Facharbeiten des Studienzeiten-durchgangs 2024/2025. Die "Studienzeiten" sind ein spezielles Angebot am Campus Zweiter Bildungsweg, das sich an die leistungsstärksten und engagiertesten Schülerinnen und Schüler des jeweiligen S1/2 richtet.

Die Studienzeiten begannen im Oktober 2024, wobei zunächst ein übergeordnetes Thema festgelegt wurde: Europa – Themen unserer Zeit. In den folgenden Monaten bis Mai 2025 lernten die Teilnehmenden wissenschaftliche Arbeitsweisen unter der Leitung von Noëlle Nowack, einer Dozentin der Universität Hamburg, kennen. Dabei wurde umfangreich gelesen, zitiert und geschrieben – eine wertvolle Erfahrumg, um erste Einblicke in das wissenschaftliche Schreiben an der Universität zu gewinnen.

Das Ergebnis der Studienzeiten können Sie und könnt Ihr hier entdecken. Wir wünschen viel Freude beim Lesen und Erkunden der vielfältigen Themen!

Der Studienzeitendurchgang 2024/2025 (Kim Berg, Nils Habben, Jonn Horstmann, Talika Kolboom, Enock Ofosuhene, Julius Lennart Pego) unter der Leitung von Noëlle Nowack

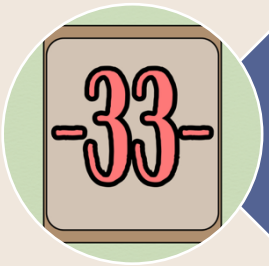
The increasing frequency of wildfires as a consequence of climate change necessitates innovating technological approaches for early detection and monitoring. This paper is concerned with two projects, KiWa and Ororatech, which have different ways to solve the detection and monitoring of wildfires. KiWa concentrates on UASs and Ororatech on nanosatellites. The second focus of the paper is to evaluate the potential of deep learning methods for fire and smoke detection and automated systems. The models FireNet and DC-Fire illustrate the theoretical applications for both projects. The comparison part concentrates on evaluating factors like cost efficiency, flexibility, weather independence and environmental impact of the two projects. Both projects benefit firefighters and other institutions and will have a huge impact, particularly if they include deep learning models in their systems. In the Future, systems with Deep Learning models could offer a promising long-term strategy for effective wildfire detection and monitoring.

Climate change threatens future generations, but we are already feeling the effects today. It is clear that the emission of climate-damaging gases into the atmosphere must be stopped. Therefore, we must not only stop our carbon dioxide emissions but also remove the excess carbon dioxide from the atmosphere.

There are various technical approaches to counter the increase in carbon dioxide in the atmosphere. One of these is the carbon capture and storage process, in which the greenhouse gas is captured and stored underground. The debate surrounding this project is very emotionally charged. This paper is therefore dedicated to a geoscientific point of view in order to come to the conclusion that we cannot guarantee safety for the next millennia.

This paper aims to draw attention to the underestimated issue of light pollution and its drastic effects on moths and to compare the different approaches to solving the

problem. The topic is influenced by geophysical, entomological, technical, economic and political aspects.



Fostering International Relations: An In-Depth Analysis of the Impact of Democracy and Autocracy on Global Engagement and Development

What is the impact of governance type – democracy versus autocracy – on a nation´s ability to form international alliances and achieve economic growth?

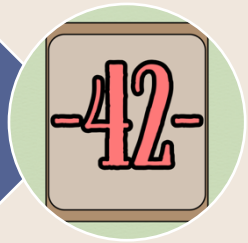
(Enock Ofosuhene)

This thesis examines how systems of governance – democracy and autocracy – affect national development and international relations, with Germany and North Korea as case studies. It explores how Germany's democratic structure supports global cooperation, economic growth, and positive diplomatic ties, while North Korea's autocratic regime contributes to international isolation and developmental limitations. By comparing these two nations, the study highlights the broader implications of governance on foreign policy, economic performance, and global standing. The findings suggest that political systems play a critical role in shaping both a country's internal progress and its relationships on the world stage.

Investigating the truth-claim of the existence of free will

To what extent are the scientific arguments on the subject of "free will" convincing?

(Julius Lennart Pego)



This paper deals with the fundamental question of whether free will exists. The establishment of a scientific consensus is important, as the construction of moral theories depends on such axioms. Furthermore, moral theories in turn influence how societies are organized and how they react to certain (critical) situations. In order to converge on the truth, the text introduces and evaluates a variety of stipulated arguments. The paper's central focus is on the examination of compatibilist and event-causal libertarian accounts. It thereby concludes that the arguments do not withstand rigorous inspection. Consequently, serious doubts are raised regarding the truth-claim of the existence of free will.

Fighting Wildfires with AI

Monitoring and detecting wildfires with the Deep Learning Models FireNet and DC-Fire

(Kim Berg)

1. Introduction

In today's age of climate change, there will be more forest fires because of increasingly dry seasons.[1] Since the industrial revolution, the global temperature has been rising, and humanity has had an enormous impact. You can see in the *Climate Change report* that the concentration of CO_2 has increased since 2000.[2] *The Copernicus Global Climate Highlights Report 2024* says that 2024 was the warmest year on record. It also says that the average temperature climbed to 1,5°C.[3] The higher temperature affects the entire world. Wildfires are breaking out more frequently in places in the forest where traditional forest fire detection can be difficult or impossible.[4] Germany is not a typical wildfire risk land but since the climate temperature raise the forests are dry. The risk for wildfires gets higher than in the past.[5] The most wildfires in Germany come from careless actions from, for example, campers in the months from May to July. In this warmest period in Germany the damage caused by wildfire is higher.[6] [7]

Furthermore, traditional forest fire detection methods are expensive and need a lot of time. It is even more important that in this highly technological age, technologies are developed to protect people, animals, and nature from these forest fires. In Germany, natural wildfires do not exist, and forests will not benefit from them. This paper deals with the topic of the two projects, KiWa and Ororatech, with two different carrier technologies for optical sensor systems and the benefits of artificial intelligence to prevent, detect, and reduce wildfires. Which technology will be the most cost-effective way to ensure the safety of the people?

To automate systems with artificial intelligence is the one of the modern technologies and in combination from different artificial intelligence systems could improve the detection of smoke or fire and could analyse automatically and decide if this smoke or little fire is a wildfire. These systems could help firefighters and other institutes to react faster.

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[1] Matt Simon: Europe has descended into the Age of Fire, WIRED, 2022 https://www.wired.com/story/europe-has-descended-into-the-age-of-fire/.

[2] ipcc: Climate Change 2021, The Physical Science Basis, 2021, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf.

[3] Copernicus: Copernicus Global Climate Report 2024 confirms last year as the warmest on record, first ever above 1,5°C annual average temperature, 2025, https://www.copernicus.eu/en/news/news/copernicus-global-climate-report-2024-confirms-last-year-warmest-record-first-ever-above#:~:text=The%20Copernicus%20Global%20Climate%20Highlights,the%20annual%20global%20average%20temperature [Stand: 12/03/2025].

[4] Parsch, Stefan: Extreme Walsbrände, Mega-Feuer nehmen weltweit zu, welt.de, 2024, https://www.welt.de/wissenschaft/article252184678/Waldbraende-Mega-Feuer-nehmen-zu.html.

[5] Uhrig, Stefanie: Wärmere Erde, Waldbrände: Ist der Klimawandel jetzt schuld – oder nicht?, Quarks, 2025, https://www.quarks.de/umwelt/klimawandel/waldbraende-klimawandel-sommer-hitze-europa-duerre/.

[6] Bundesministerium für Ernährung und Landwirtschaft: Waldbrandstatistik, Waldbrandstatistik 2023: Fläche von rund 1771 Fußballfeldern verbrannt, 2023, https://www.bmel-statistik.de/forst-holz/waldbrandstatistik [Stand: 09/04/2025].

[7] Hirschberger, Peter, Griesshammer, Nina, Winter, Susanne: Verbrannte Erde, Ursachen und Folgen der weltweiten Waldbrände – und was wir dagegen machen können, WWF, 2021, https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Wald/WWF-Studie-Verbrannte-Erde-Ursachen-Folgen-Waldbrand-Deutschland.pdf [Stand: 12/03/2025].

2. Project “KiWa”

The project “AI-based Forest Monitoring-Artificial Intelligence for Early Detection of Forest Fire Events“ (KiWa) is a combination of the five project partners, Urban Mobility Innovations (ui!), Quantum-Systems GmbH, Technischen Hochschule Deggendorf, Universität Bayreuth and the Staatlichen Feuerwehrschule Würzburg, who wanted to create an unmanned Aerial System and will use innovative technologies to support firefighters and disaster control organization. The project was state-funded with 1.8 million euros by the German Federal Ministry for the Environment.[8]

2.2 Unmanned Aircraft Systems (UAS)

Unmanned Aircraft Systems (UAS) do not need pilots. They are also known as drones and often describe aircraft that are wirelessly controlled by a drone pilot. UASs are smaller than regular aircraft and can be powered by petrol or electricity.

2.3 UAS - A new Methode for wildfire monitoring

The project uses the Unmanned Aircraft System (UAS) Trinity Pro with optical sensor systems developed by Quantum-Systems GmbH. This UAS is the best and cheapest alternative option than the classical options. The Trinity Pro is at estimated value of fifty thousand US Dollar when comparing other equipment.[9] Classic methods were to fly a propeller plane over the forests and areas with high risk of wildfires. You need a lot of personnel for this Watching-overflights, because you need one pilot and another person to observe the areas. The need for time of personnel and costs was high. With the use of a UAS you do not need many personnel anymore. Further there are some running costs. You must rent a hangar which could cost from one hundred euros to over one thousand euros[10], has cost for kerosene and maintenance. The fixed cost could reach more than thirty thousand euros. The Trinity Pro installation is easy to handle and use by one person. It does not need a hangar or kerosene, which is also suitable for the climate.[11]

In some regions the firefighters used towers to monitor a huge hectare of a Forest area. These towers are not flexible enough and some areas you cannot reach normally are challenging to monitor. Here is the benefit that the Trinity Pro from the project KiWa is flexible and you can reach all areas. From the starting point the drone pilot can reach seven hundred hectares and fly ninety minutes.[12] This flexibility also benefits the institutes, who need to monitor the areas, can install and use the UAS every time. Systems that use pictures from satellites have the problem that the satellites overflight an area once a day. UAS gives the option to overflight high risks areas more than ones a day.

Optical Sensors have a benefit over air sensor systems. Air sensor systems are affected by wind and rain. If the wind blows in a false direction, the wildfire warning system is unprecise. Optical sensors are not affected by wind and will send precise data.

The opposite is that the institutes that use the UAS need trained staff. To fly an UAS is not easy and no allowed everywhere. You need a license to legally fly a drone in the European Union and Germany. The Trinity Pro weighs more than 5 Kilograms so the institute could need special approval to use the drone.[13]

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[8] KiWa: KIWA startet!, 2023, https://www.kiwa-projekt.de/kiwa-startet [Stand: 12/03/2025].

[9] Measur: Next Generation e-VTOL Fixed-Wing Mapping Drone, https://measurusa.com/products/trinity-pro?utm_source=chatgpt.com&shpxid=dd2915a4-98a8-44cb-b44b-5b36bfaa320a [Stand: 12/04/2025].

[10] Borchert, Thomas: Betriebskosten, fliegermagazin, 2020, https://www.fliegermagazin.de/wissen/betriebskosten/#google_vignette

[11] KiWa: KIWA, Die innovative Antwort auf die steigende Waldbrandgefahr, KIWA, 2023, https://www.kiwa-projekt.de/innovative-antwort-auf-die-steigende-waldbrandgefahr.

[12] Quantum Systems: Trinity Pro, Next-generation eVTOL fixed-wing mapping drone, https://quantum-systems.com/trinity-pro/ [Stand: 11/03/2025].

[13] Bundesministerium für Digitales und Verkehr: EU-Regelungen für Drohnen, 2021, https://bmdv.bund.de/drohnen [Stand: 13/04/2025].

KiWa wants to automate wildfire detection with deep learning systems. Deep Learning is a part of the generic term artificial intelligence. With the view to optical sensors, the best way is to use colour and texture models. You can classify the characteristics of fires into colour and texture. CMOS imaging sensors produce high-solution images of fire and smoke, and many UAVs are equipped with these sensors.[14] A simple Smoke Detection Algorithm is the Local Binary Patterns. The image or Frames from a video will be converted to an LBM-Motion Image, which means that the RGB-Image will convert to a Gray-Image to identify the texture of the smoke. In combination with a Gaussian Filter, an HSV-Image converts back to RGB, and the deep learning method classifies the image and decides if this image shows wildfire or not. The classifier uses MobileNetV3 (the outdated version is the MobileNetV2).[15] The Fire_Net Model is based on a Deep Convolutional Neural Network Model (DCNN-Model) and works with fifteen layers for the complex image identification of fire and smoke. This model is based on pixel classification for fire and uses the RGB and YCbCr colour space for forest fire tracking. The Fire_Net Model combine the texture Models to identify. The first step is localising the fire area to find the “region of interest”[16] because the UAS´s image sensors are mostly wide-angle images. To see the essential part of the fire, we use the saliency method, which extracts and converts a vector image of the fire. This vector image will be compared with the DCNN-Model knowledge and identify fire or no-fire.[17] These trained Models are highly precise and reach over 95% Accuracy.[18]

3. From research project to Startup - Ororatech

Ororatech is a project and space tech startup in Munich. The founders, Thomas Grübler, Rubert Amann, Florian Mauracher and Björn Stoffers, transformed the university project into a Startup that wants to prevent, monitor and fight wildfires from space with satellites which work with thermal imaging sensors. They constructed a mini satellite and launched the first, Forest 1, into low-earth orbit in 2022.[19] The following two satellites were launched in 2023 (Forest 2)[20] and 2025 (Forest 3)[21]. With the Forest 3 satellites, they changed the configuration to a more petite body. Ororatech partnered with Spire and used their constellation of satellite bodies and communication methods.

3.1 Nanosatellites with thermal-infrared imaging sensorics monitor the world

The development of the Nanosatellites from Ororatech and Spire will change monitoring, fighting, and preventing wildfires all over the world. Nanosatellites are little Cubes which will be send with a rocket into space. Nanosatellites weigh between 1 kg and 10 kg.[22] Ororatech´s satellites in the low orbit will monitor every area in the world more than once and monitor twenty-four hours per day. Preventing and fighting wildfire is cheaper for countries than using the classic methods.

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[14] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p.3.

[15] Shi, Jie, Wang, Wei, Gao, Yuanqi, Yu Nanpeng: Optimal Placement and Intelligent Smoke Detection Algorithm for Wildfire-Monitoring Cameras, IEEE Access, 2020, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9068226 p. 72330 – 72331.

[16] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p. 5.

[17] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p. 11 - 12.

[18] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p. 13 Table 5.

[19] OroraTech: About us, We empower those who protect our world, one decision at a time, https://ororatech.com/company/about-us#90 [Stand: 01/04/2025]

[20] Gunter´s Space Page: Forest 2, https://space.skyrocket.de/doc_sdat/forest-2.htm [Stand: 13/03/2025].

[21] Gunter´s Space Page: Forest 3, https://space.skyrocket.de/doc_sdat/forest-3.htm [Stand: 13/03/2025].

[22] Kulu, Erik: What is a CubeSat & other picosatellites, https://www.nanosats.eu/cubesat [Stand: 13/03/2025].

Ororatech is using the Nanosatellites Cubes from Spike. Forest 1 and Forest 2 used the CubeSat 6U from Spire´s Lemur-2 cubesat which is customized for Ororatech.[23] The Forest 2 got a new model[24] which is equipped with the self-development thermal imager[25], using the newest Nanosatellites the Forest 3, a multispectral thermal imager module using long-waves and middle-wave Infrared. The Forest 3 got a new corpus which is CubeSat 8U. The company has a big amount of investment because they must first finance the production and development of the satellites and infrared module. The launch of the nano satellites with spaceX is expensive. Ororatech used for the transport to the low orbit the “smallsat rideshare program” which says that the cost for a start will be lower as three hundred thousand Us Dollar[26]. In the future Ororatech will send over one hundred nano satellites by 2026. If we take the prize of three hundred thousand US Dollar, the cost only for the starts will rise to thirty million US Dollar. With fundraising and programs from different nations they finance their first starts because they need some nano satellites in the orbit to start their product for monitoring wildfires. The benefit for the User is that they only need to pay for the service and do not need to buy other equipment excluding computer equipment, which is cheaper than any drones, renting or buying propeller planes or need personnel for watchtowers.
The monitoring of wildfires with Ororatech will not be affected by climate. It will work every time and every day and can also see through smoke. The digital version of the program will be reachable in any area with digital connections.
The Forest-3 satellite works with a GPU and processes information from the long-wave module, middle-wave infrared module, and the optical camera module on board. This happens in real time and sends the combined information directly to earth using inter-satellite-modem. This is a benefit for the institutes because they do not need to first start anything like drones that need time. The information about wildfires will be sent in real time to their communications systems and they can react faster to fight wildfires and protect animals and humans.
The orbit around the earth is a graveyard for old technology. Since space travel began in October 1957[27] there are more than seven hundred satellites in use today. The number of unused satellites and rockets which drift around the earth is already innumerable and this orbital garbage mountain grows every year by five percent[28]. Ororatech will send one hundred satellites in this overflowing orbit until 2026. Their satellites are small and are sized like a shoes-box, but every satellite and rocket will use more space until the orbit is full and the danger of hit orbit-garbage rises. This is the biggest problem for the world and the orbit, that the nano satellites from Ororatech will feed the orbit-garbage problem. In the next years Ororatech will improve their technology and after the reach of one hundred satellites they could send newer satellites to replace older satellites.
For the communication between the earth and the satellites Ororatech must build a lot of antenna stations and need some operation stations near hotspot areas. The dates from the camera modules are large and so the users will firstly get only an alert and then over public satellites stations the datasets of the wildfire. The antenna stations should eliminate interruptions and delays during the connection. These stations need to be built all over the world, and someone must maintain regularly otherwise they cannot benefit from the real time monitoring.

4. Deep Learning the new Archievement of humanity

Deep Learning is part of the generic term of Artificial Intelligence, which describes the technological development in this century. Especially is Deep Learning a neural network-based

[23] Gunter´s Space Page: Forest 1, https://space.skyrocket.de/doc_sdat/forest-1.htm.
[24] Gunter´s Space Page: Forest 2, https://space.skyrocket.de/doc_sdat/forest-2.htm [Stand: 13/03/2025].
[25] Justia Parents: Uncooled thermal imager, 2024, https://patents.justia.com/patent/12192671.
[26] SpaceX: Smallsat Rideshare Program, https://www.spacex.com/rideshare/ [Stand: 13/03/2025].
[27] AEROSPACE: A Brief History of Space Exploration, Aerospace, https://aerospace.org/article/brief-history-space-exploration#:~:text=On%20Oct.,orbit%20Earth%20in%20Vostok%201. [Stand: 14/03/2025].
[28] European Space Agency: Im Orbit wird es eng, esa, 2002, https://www.esa.int/Space_in_Member_States/Austria/Im_Orbit_wird_es_eng.

method that is one part of Machine Learning and will explicitly be used, for example, image analysis and comparison. Machine Learning works for problem-solving and can imitate Humanity based on learned knowledge and rule-based algorithms. Deep Learning is a small part of Artificial Intelligence and is sufficient for wildfire detection.[29]
One of the Deep Learning Neural Network Systems is the MobileNetV3 and the older Version MobileNetV2. This network is specially designed for systems with less space and can be used for mobile and other small devices. MobileNet is suitable for Deep Learning and image analysis.[30]

4.1 Identifying Wildfires using Deep Learning model FireNet

KiWa wants to automate wildfire detection with deep learning systems. Deep Learning is a part of the generic term artificial intelligence. With the view to optical sensors, the best way is to use colour and texture models. You can classify the characteristics of fires into colour and texture. CMOS imaging sensors produce high-solution images of fire and smoke, and many UAVs are equipped with these sensors.[31] A simple Smoke Detection Algorithm is the Local Binary Patterns. The image or Frames from a video will be converted to an LBM-Motion Image, which means that the RGB-Image will convert to a Gray-Image to identify the texture of the smoke. In combination with a Gaussian Filter, an HSV-Image converts back to RGB, and the deep learning method classifies the image and decides if this image shows wildfire or not. The classifier uses MobileNetV3 (the outdated version is the MobileNetV2).[32] The Fire_Net Model is based on a Deep Convolutional Neural Network Model (DCNN-Model) and works with fifteen layers for the complex image identification of fire and smoke. This model is based on pixel classification for fire and uses the RGB and YCbCr colour space for forest fire tracking. The Fire_Net Model combine the texture Models to identify. The first step is localising the fire area to find the “region of interest”[33] because the UAS´s image sensors are mostly wide-angle images. To see the essential part of the fire, we use the saliency method, which extracts and converts a vector image of the fire. This vector image will be compared with the DCNN-Model knowledge and identify fire or no-fire.[34] These trained Models are highly precise and reach over 95% Accuracy.[35]

4.2 Infrared image analysis with Deep Learning model DC-Fire

There are a lot of Deep Learning models for flame and smoke identification, which use infrared images and often combined visible and infrared images. This paper will concentrate on the model DC-Fire to show how Deep Learning could operate with the satellite systems from Ororatech.
DC-Fire used two different Convolutional Neural Networks (CNN) to analyse infrared images and identify a fire.[36] One of them is DenseNet-201 for an efficient way to get highly accurate

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[29] Kobold.AI: Machine Learning vs. Deep Learning: Was ist der Unterschied?, https://www.kobold.ai/ml-vs-dl/#:~:text=Der%20Unterschied%20zwischen%20Machine%20Learning,die%20auf%20neuronalen%20Netzen%20basiert [Stand: 08/04/2025].
[30] Singh, Rishabh: Understanding and Implementing MobileNetV3, Medium, 2024, https://medium.com/@RobuRishabh/understanding-and-implementing-mobilenetv3-422bd0bdfb5a.
[31] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p.3.
[32] Shi, Jie, Wang, Wei, Gao, Yuanqi, Yu Nanpeng: Optimal Placement and Intelligent Smoke Detection Algorithm for Wildfire-Monitoring Cameras, IEEE Access, 2020, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9068226 p. 72330 – 72331.
[33] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p. 5.
[34] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p. 11 - 12.
[35] Zhao, Yi, Ma, Jiale, Li, Xiaohui, Zhang, Jie: Sliency Detection and Deep Learning-Based Wildfire Identification in UAV Imagery, 2018, https://www.mdpi.com/1424-8220/18/3/712 p. 13 Table 5.
[36] Ghali, Rafik, Akhloufi, Moulay A.: DC-Fire: a Deep Convolutional Neural Network for Wildland Fire Recognition on Aerial Infrared Images, Qirt Asia 2023, 2023, http://qirt.gel.ulaval.ca/archives/qirt2023/papers/QIRT-ASIA-2023_paper_3.pdf p. 2; Ghali, Rafik,

image parameters without losing any of them. It works with Dense Blocks which analyse the image for characteristics and the output layer will be polished. This polished layer will be used for the next analyse in the successive Dense Block and the hole process repeat multiple times. With this process the model reduces transition losses.[37] The second method is EfficientNet-B5 scaling three scaling dimensions to get more pixel from the original image. The second benefit is that this method needs less network resource
s that other methods.[38] The result of this models can be used to identify with the sigmoid function a fire or No-Fire.[39]
Trainings with DC-Fire shows an accuracy of 100 % and an F1-score of one hundred percent[40] in comparing with other methods. For the test was using the Dataset Flame2 which contains 53451 images from real wildfires and without wildfires.[41]

5. Comparative Evaluation of KiWa and Ororatech

Both projects, KiWa and Ororatech, aim to improve wildfire detection using artificial intelligence and optical sensor systems, but they follow two completely different approaches regarding hardware, implementation, and operational strategies.
The KiWa project focuses on using Unmanned Aircraft Systems (UAS) which have lower entry costs than Ororatech. In comparing the two projects we must aim the focus on using hardware that both used. KiWa uses the Trinity Pro, which is a drone whose estimated cost is fifty thousand US Dollar and the Ororatech Project, which focuses on using nanosatellites, has more costs before fully starting the project. Ororatech has developed nanosatellites with fitting hardware, and their most cost input is the rocket launches, which could be more than three hundred thousand US Dollar. In the end both projects have ongoing costs for personnel and hardware for example for server structure, but KiWa need trained personnel to fly the drones. On the other hand, Ororatech cannot reach the satellite or hardware to repair. Ororatech must build a new nanosatellite and must send him to the orbit. In this point the repair cost of a drone is cheaper than any satellite.
KiWa has the advantage of being highly flexible for users. The drone is assembled quickly for one person and ready for use anywhere and every time. For Institutes of firefighting is the spontaneous and flexible usage of KiWa advantageous because they know it is in the reach the hole time. Ororatech´s nanosatellites do not reach the goal of a twenty-four seven coverage. Institutes must wait that the satellite to be in the right position and a data downlink is available which a drone does not need.
Both systems use different sensor technology. KiWa uses optical sensors that give visible images and Ororatech works with thermal infrared imaging. The benefits of infrared sensors are that it works through fog and will not be affected by the weather. However, KiWa will be affected by the weather situation and the drone cannot fly during the storm and other extreme weather. The satellites are higher than the weather zone and fly over the weather and can still monitor the wildfire situation.
At least both systems have different impacts for the environment on earth and the orbit. The drone can fly electrically and does not need any fuel. The satellites do not use fuel in the end

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Akhloufi, Moulay A.: Deep Learning Approach for Wildland Fire Recognition Using RGB and Thermal Infrared Aerial Image, mdpi, 2024, https://www.mdpi.com/2571-6255/7/10/343# p. 7.
[37] Huang, Gao, Liu, Zhuang, van der Maaten, Laurens, Weinberger, Kilian Q.: Densely Connected Convolutional Networks, 2018, https://arxiv.org/pdf/1608.06993 p.2-3, Figure 2 [Stand: 12/04/2025].
[38] Tan, Mingxing, Le, Quoc V.: EfficientNet: Rethinking Model Scaling for Convolutional Neural Networks, 2020, https://arxiv.org/pdf/1905.11946 [Stand: 12/04/2025] p. 3-4.
[39] Ghali, Rafik, Akhloufi, Moulay A.: DC-Fire: a Deep Convolutional Neural Network for Wildland Fire Recognition on Aerial Infrared Images, Qirt Asia 2023, 2023, http://qirt.gel.ulaval.ca/archives/qirt2023/papers/QIRT-ASIA-2023_paper_3.pdf p. 2.
[40] Ghali, Rafik, Akhloufi, Moulay A.: DC-Fire: a Deep Convolutional Neural Network for Wildland Fire Recognition on Aerial Infrared Images, Qirt Asia 2023, 2023, http://qirt.gel.ulaval.ca/archives/qirt2023/papers/QIRT-ASIA-2023_paper_3.pdf p.3 Table 2.
[41] Ghali, Rafik, Akhloufi, Moulay A.: Deep Learning Approach for Wildland Fire Recognition Using RGB and Thermal Infrared Aerial Image, mdpi, 2024, https://www.mdpi.com/2571-6255/7/10/343# p. 6 Table 1.

position but burn a lot of fuel during the start with the rockets. KiWa has a better CO_2 output than the Ororatech project with its rocket starts. Another point is that the satellites cannot be recycled because there is not the possibility to collect them in orbit, and the garbage in orbit is increasing. Drones from KiWa project can be recycled and the resources will be used.

6. Conclusion

The impact of wildfires on humanity will increase over time, and it will be important to find ways to detect wildfires and reduce their consequences. Both projects have good points and will be important in the future.

In the future, the Ororatech project will become a faster opportunity for detecting wildfires, especially if Ororatech reaches his goal of sending enough nanosatellites to detect twenty-four seven wildfires in any spot on the planet. The most significant advantage is that the satellite technology will not be affected by weather conditions and can work and see wildfires during smoke, fog, and other situations. However, Drones are now the best way for institutions to detect in their region. In particular, Ororatech does not have any satellites on the spot. In the distant future, both technologies could be a good combination for the detection, especially with the use of Deep Learning, the detection will become faster and could be automated with the nanosatellites. The system identifies a wildfire and sends information to all important institutions.

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Carbon Capture and Storage in Europe – a geological resumé

How can we guarantee safety of carbon dioxide deposits for ten thousand years?

(Nils Habben)

1. Introduction

At the beginning of the industrial age, the concentration of carbon dioxide in the atmosphere was 280 parts per million (ppm), today it is 480ppm and the concentration continues to rise which cause the global warming. The increase of the carbon dioxide level in the atmosphere is linked to the accumulation of extreme weather events, such as droughts and storms, which global appearance increases. This is caused as not only the carbon dioxide level in the atmosphere continues to rise but carbon dioxide emissions are increasing too.[42]

This increase in carbon dioxide concentrations is caused by humans and their hunger for energy. Although many of the largest industrialized nations have committed to limiting carbon dioxide emissions in order to limit the rise in global temperature to 1.5° Celsius by 2100. This was decided at the Paris Climate Conference in 2015. Nevertheless, the amount of carbon dioxide in the atmosphere continues to rise.[43]

This is often due to a lack of political will to enforce environmental protection laws, but also to a lack of technical possibilities in many production sectors such as steel and cement production.[44] Research is therefore being carried out into techniques to collect carbon dioxide where it is produced and to extract carbon dioxide directly from the atmosphere. The technique of capturing the gas direct from the source is called Post Combustion Capture. The technique to capture it directly from the air is called Direct Air Capture. In both cases, the gas should then either be used for other purposes or stored underground. The latter is to be done in such a way that it is safely stored for thousands of years without endangering the environment or us.[45]

While proponents of the technology celebrate it as a beacon of hope for actively combating climate change without changing our lifestyles, others warn that there are foreseeable dangers that far outweigh the potential benefits.

A benefit from the Post Combustion Capture might be the possibility to use fossil fuels much longer as well as some industrial processes must not be overthought because for some branches it is difficult to decrease the amount of carbon dioxide they produce. The Direct Air Capture technologies can lower the amount of the exhaust of carbon dioxide or even lower the amount of carbon dioxide in the atmosphere directly.

The dangers which these technologies have in common is the storage part. While there are some scientists who are researching if the captured carbon dioxide can be utilized as a source of carbon in other sectors of the industry the most controversial debate is about the storage of carbon dioxide. For storing carbon dioxide old oil and gas wells shall be used. First, they use old wells beneath the northern and the Baltic seas. These wells are in rock layers which must be stable against tectonically interruptions for thousands of years. Our earth's surface appearance is caused by huge processes like plate tectonics, eruptions and earthquakes.

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[42] Cook, John: Behauptung: „Der CO2-Anstieg ist nicht Ursache, sondern Folge des Klimawandels". *Klimafakten.de*. 2010/2022, https://www.klimafakten.de/klimawissen/fakt-ist/fakt-ist-co2-ist-die-hauptursache-des-gegenwaertigen-klimawandels-auch-wenn.

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[45] Bundesministerium für Wirtschaft und Klimaschutz: FAQ zu CCS und CCU. 2024, https://www.bmwk.de/Redaktion/DE/Downloads/F/faq-ccs-ccu.pdf?__blob=publicationFile&v=6.

These processes never stand still which leads to the question can it be possible to make sure that these storages can be safe for us, future generations and the environment? To answer this question the paper starts with an introduction into geological processes which led to Europe's surface as we know it today by considering what happened in the earth's past, what is still happening and how might Europe change in the next thousands of years. The next step will be to explain which techniques are in use to capture, transport and storage carbon dioxide. After this the paper will list and discuss the possible as well as real benefits and dangers. In the conclusion the question if it is possible to store carbon dioxide with these techniques permanently will be answered.

2. Geological processes

In order to understand where which geological processes take place, one must first understand why these processes exist. Only with a rough understanding of these mechanisms certain areas can be excluded for the storage of carbon dioxide.

2.1 Plate tectonics

Based on the analysis of the decay rate of isotopes within dust particles and meteorites that were formed at the beginning of the solar system, it is currently assumed that planet Earth formed approximately 4.6 billion years ago.[46] During the beginning gas and dust formed a first a loose ball which more and more solidified until a solid rock was formed. Due to collision of this planetesimal with other planetesimals and asteroids it became denser. The bigger the collisions became, the more power developed and more heat developed too. The potential energy of the collisions was converted into thermal energy, which still accounts for most of the Earth's internal heat today. This melted the rocks of which the protoplanet consisted and a ball of liquid rock was formed. About 4.4 billion years ago, a crust formed on the surface due to cooling, which further ensured that the heat could hardly escape from the interior of the planet and the interior remained liquid. In this liquid interior, the different molten materials were homogeneously mixed until it separated into the layers that form the interior of the Earth today: Earth's core, mantle and crust.
About 4.2 billion years ago, the surface had cooled down enough for liquid water to collect. This water was ejected as water vapor by volcanoes, but comets, which consisted of water ice, also provided water and the first ocean began to form. About 4 billion years ago, the previously closed crust broke apart and individual continental plates formed. This process is due to mantle convection, which occurs when the pressure and temperature inside the earth increase with depth. This ensures that heated material rises from the deeper layers of the earth's mantle, while cooler material sinks into the depths. This creates convection currents in the Earth's mantle. These currents ensure that the earth's crust also moves, pushing one continental plate under another or colliding with another, causing mountains to rise. This movement of the continental plates is called plate tectonics and changes the earth surface until this day.[47] Today a distinction is made between seven large and several smaller continental plates. Present's plates are the result of various collisions and break-ups in the Earth's past and move by 1 to 2 centimeters every year. Where the plates meet or move away from each other, volcanic eruptions or earthquakes occur again and again. Most of today's low mountain ranges in Europe are the result of such continental encounters. Europe is part of the Eurasian continental plate, which borders the North American plate to the west and east and the Arabian, Indian and Australian plates to the south. The North American and Eurasian plates drift apart in the west by 2 centimeters per year. This zone is called the Mid-Atlantic Ridge, as the outflow of molten rock, magma, has created an undersea mountain range here. Iceland is located on this ridge and was formed directly as a result of volcanic activity in the region, which still continues today and shapes the appearance of the island.[48]

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[46] Dalrympl, G. Brent: The Age of the Earth. 1. Auflage, 1994.
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[48] Kious, W. Jacquelyne/ Tilling, Robert I.: The Dynamic Eart: The Story of Plate Tectonics. 1. Auflage, 1996; Reuther, Claus Dieter: Grundlagen der Tektonik. 1. Auflage, 2012.

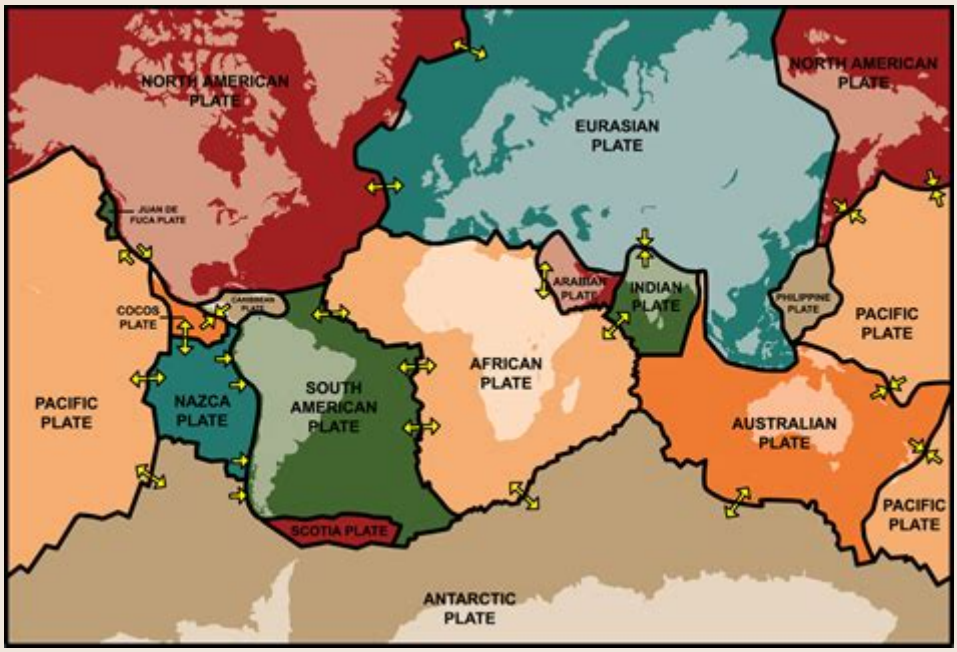

Figure 1: Plate tectonics. An overview of the major tectonic plates. The yellow arrows show where the plates are moving to.[49]

2.2 Volcanism

As volcanic eruptions have a considerable potential for damage, it is important to clarify where volcanism takes place. According to the German dictionary and Oppenheimer and P. Francis, volcanoes and volcanism are defined as follows:

A volcano is a geological structure through which magma and other solid and gaseous substances emerge from the earth's interior to the surface during periods of volcanic activity.[50]

Volcanism is a superficial expression of internal heat on planets or moons, causing solid, liquid or gaseous products to spread over the surface.[51]

Volcanoes are essentially formed in three places, which are briefly explained below.

2.2.1 Subduction zones

A subduction zone is the area where one continental plate submerges under another. In this zone, friction and pressure cause the rock to melt. This melt makes its way and forms a chain of volcanoes on the upper plate, which is called a volcanic arc.[52] An example for an active volcanic area which is based on a subduction zone are the Phlegraean Fields in Italy.[53]

2.2.2 Volcanic hotspots

There are also volcanoes that form on the continental plates and not on their edges. These are caused by a convection structure known as a mantle plume. These are flows of molten material from the deeper layers of the Earth's mantle which move in a columnar shape towards the crust and widen there in a mushroom shape. These plumes can form magma chambers by melting as magma penetrates cracks in the earth's crust. If the pressure in such a chamber is high enough, the magma rises towards the earth's surface and leads to volcanic activity. These places are known as volcanic hotspots.[54] In Europe, one such volcanic hotspot has so

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[49] Bildquelle: https://cdn.shortpixel.ai/spai/q_lossy+w_1252+h_850+to_auto+ret_img/cosmosmagazine.com/wp-content/uploads/2014/09/tectonic-1.jpg.

[50] DWDS: Vulkane. *Digitales Wörterbuch Deutscher Sprache*, https://www.dwds.de/wb/Vulkan.

[51] Francis, P./Oppenheimer, Clive: Volcanoes. 2nd Edition, 2003.

[52] Spooner, Alecia M.: Geologie für Dummies. 1. Auflage, 2016.

[53] Smithonian Institution: Campi Flegrei. 2024, https://volcano.si.edu/volcano.cfm?vn=211010.

[54] Campbell, Ian H.: "The case for mantle plumes". 2007, https://www.mantleplumes.org/Plumes.html.

far been identified in the Eifel region in Germany.[55] Research is still being carried out into whether and when another outbreak could occur. To this end, 12 new measuring stations are currently being implemented in addition to the 28 existing ones. Based on the current situation, however, an eruption is not expected in the next few millennia.[56]

2.2.3 Mid-ocean Ridges

Where two continental plates move away from each other, a so-called mid-ocean ridge is formed. Magma rises through cracks at these points, cools there and forms a mountain range. One example of this is the mid-Atlantic ridge on which Iceland is located.[57]

2.3 Earthquakes

Earthquakes are defined as tremors in the earth. They are seismic energy that moves through the earth's crust in waves. According to the Swiss Seismological Service, earthquakes can be divided into four categories depending on the cause:

- Tectonic quakes: Plate tectonics causes stresses to build up along the edges of the plates, suddenly discharging them. They occur most frequently.
- Volcanic quakes: As a result of volcanic activity. Are usually not as strong as tectonic quakes.
- Collapse earthquakes: Are triggered by cave-ins or landslides.
- Induced earthquakes: Triggered by external influences such as meteorite impacts, nuclear explosions, mining, petroleum and gas extraction or the injection of gas or fluids.[58]

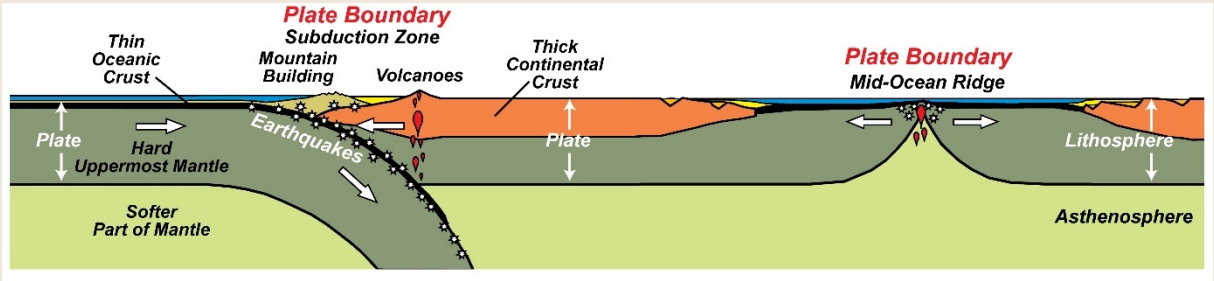

Figure 2: A visualization of the continental movement and how it appears on its surface.[59]

Accordingly, earthquakes represent a risk that should not be underestimated, which is explained in more detail in Chapter 3.3.

2.4 Petroleum and Gas

Petroleum and natural gas are hydrocarbons that are formed at depths of more than 1000 meters and are classified as fossil fuels. Both are among the world's most important energy sources, which together provide around half of the energy supply.[60]
Petroleum was formed by dead microorganisms which were deposited in shelf seas together with clay and sand minerals and pressed further and further over millions of years in the absence of oxygen. Crude oil is formed in a temperature range of 60° to 120° Celsius, which

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[55] Schmincke, Hans-Ulrich: Vulkane der Eifel: Aufbau, Entstehung und heutige Bedeutung. 2009.
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[60] World Energy Council: Energie in der Welt: Zahlen und Fakten. 2023, https://www.weltenergierat.de/energie-fuer-deutschland-2023/energie-in-der-welt-zahlen-und-fakten/?cn-reloaded=1.

is known as the oil window. These conditions usually prevail at a depth of 2000 to 4000 meters where the necessary pressure is present to form oily, fine-grained rock from the sediments. These petroleum-containing rocks are known as source rocks. Due to the difference in density, petroleum and gas, which also forms in most oil reservoirs, migrate through porous surrounding rock towards the earth's surface. It is often stopped on its way by an impermeable layer of rock and collects underneath it. The rocks in which the petroleum collects are called reservoir rocks. It can also happen that the petroleum reaches the earth's surface and can be extracted there in open-cast mining. Underneath the collected petroleum is groundwater in the pore rock which is denser than the petroleum. Bigger sources of petroleum in Europe are found in Norway, Great Britain, Romania, Denmark, Italy, Germany and Turkey.
Most natural gas originated from dead plants, which were also covered airtight by sediments. Natural gas requires higher temperatures to form than petroleum to emerge. So, it needs Temperatures from 120° to 180° Celsius. Otherwise, it takes mostly the same way as petroleum. It migrates as well to the earth surface and collects in porous stones like sandstone. If natural gas reaches the earth surface it escapes to the atmosphere. The biggest extraction of natural gas in Europe are settled in Norway, Great Britain and Romania.[61]

2.4.1 Extraction methods

During extraction, a distinction is made between conventional and unconventional deposits. This refers to the rock in which the raw materials are found. Conventional deposits are porous rocks from which the raw materials can be easily extracted. In the case of petroleum, this also relates to the viscosity of the source material. Unconventional deposits can only be developed with greater technical effort. This can be the case if the rock is not porous and therefore impermeable or if the source material is not viscous enough, as can be the case with bitumen as a source material. Extraction takes place on land, known as onshore, and under water, known as offshore.[62]

2.4.1.1 Conventional deposits

Conventional deposits are deposits consisting of porous rock from which petroleum and natural gas can be extracted with comparatively little technical effort. The crude oil is present in a viscous form. These deposits are developed by drilling and subsequent pumping. This usually takes place in three phases:

- Primary production: Here, the surrounding pressure is sufficient to transport the petroleum and natural gas to the surface.
- Secondary production: When the pressure of the reservoir drops, water or natural gas is pumped into the reservoir to increase the pressure and yield again.
- Tertiary extraction: The use of steam, surfactants, nitrogen, carbon dioxide, microorganisms or other chemical agents is used in an attempt to increase the petroleum yield. These agents are intended to increase the viscosity of the remaining petroleum and make it easier to separate from the rock.

The aim of the three-stage extraction process is to exploit as much of the petroleum and natural gas reserves as possible. However, the yield is usually only between 50% and 70% of the total deposit.[63]

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[61] Pusch, Günter: Entstehung von Erdöl und Erdgas. https://www.erdoelmuseum.de/index.php/technik/98-entstehung-von-erdoel-und-erdgas; Landesamt für Bergbau, Energie und Geologie: Energierohstoffe Erdöl und Erdgas. https://www.lbeg.niedersachsen.de/energie_rohstoffe/erdoel_und_erdgas/energierohstoffe_erdoel_und_erdgas/energierohstoffe-erdoel-und-erdgas-603.html.

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[63] Aleklett, Kjell/Hirsch, Robert/Höök, Michael: Giant oil field decline rates and their influence on world oil production. *Energy Policy,* Volume 37, 2009, https://doi.org/10.1016/j.enpol.2009.02.020.

2.4.1.2 Unconventional deposits

Unconventional deposits are those that do not consist of permeable rocks and therefore require a higher technical effort to develop the fossil fuels. These are:

- Shale gas/shale oil deposits: Here, the raw materials are stored in impermeable clay minerals. In order to exploit these, so-called “fracking” is used, in which water and chemicals are pressed into the rock under high pressure to break it up.
- Oil sand: A mixture of sand and petroleum that occurs at shallow depths and also on the surface. Although these are easily mined, they require a more complex process to separate the petroleum from the sand.
- Coal seam gas reservoir: Here, natural gases such as methane are stored in coal seams, which are drilled to allow the gas to escape. It is also known as mine gas.
- Aquifer gas reservoir: This is gas that is dissolved in groundwater.
- Gas hydrate deposit: Under high pressure, water forms methane hydrate with methane. Methane hydrate then occurs as nodules. There are plans to exploit these deposits through deep-sea mining.[64]

2.4.2 Depleted wells in Europe

There are different depleted petroleum and natural gas wells in Europe especially in Germany, Italy, Romania and the northern sea. Many depleted gas deposits are also used to store natural gas and shall also be used to store carbon dioxide in the future. According to the Geological Survey of Denmark and Greenland, the total capacity for carbon dioxide in depleted natural gas and petroleum reservoirs is 28 billion tons, with a capacity of around 2 to 8 billion tons in the fields located in the North Sea.[65]

3. Carbon Capture and Storage

The idea of capturing and storing carbon dioxide was developed back in the 1970s. In the following decades, technologies were tested and have been implemented in the Norwegian gas fields called Sleipner since 1996. There the extracted natural gas is cleaned of carbon dioxide which is then pumped back underground. Since then, the capture and storage of carbon dioxide has been researched further and is seen as a beacon of hope for a climate-neutral future.[66]

3.1 Carbon Capture

- Post-combustion capture: Existing processes for scrubbing combustion gases from power plants are being expanded to include carbon dioxide scrubbing. This involves treating the flue gas with alkanoamides, which combine with the carbon dioxide.
- Pre-combustion capture: In a technical process, when an energy source is vaporized, the gas is converted into a synthesis gas. This synthesis gas is then split into hydrogen and carbon dioxide. The latter is then separated.
- Oxy-combustion: Oxygen is extracted from the air and added to the combustion process to achieve a higher flame temperature and thus a higher conversion of carbon into carbon dioxide.

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[64] Cremonese, Lorenzo/Ferrari, Michele/Flynn, Marianne P./Gusev, Alexander/Lorenz, Nicola/Stückrad, Stefan: Unkonventionelles Erdgas. *IASS FACT SHEET,* 03/2014, https://www.rifs-potsdam.de/sites/default/files/files/rz_fact_sheet_150313_digital_de.pdf.

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[66] Ma, Jinfeng/Li, Lin/Wang, Haofan/Du, Yi/Ma, Junjie/Zhang, Xiaoli/Wang, Zhenliang: Carbon Capture and Storage: History and the Road Ahead. *Engineering,* Volume 14, 2022, https://doi.org/10.1016/j.eng.2021.11.024.

- Pyrogenic carbon capture and storage: Here, plant material is carbonized in the absence of oxygen. The output product can then be used in various applications such as soil improvement.[67]

3.2 Carbon Storage

There are multiple options to storage carbon as carbon dioxide:

3.2.1 Aquifers

Aquifers are porous or highly fissured rock layers in which groundwater can flow. These are bounded by layers of rock that are impermeable to water. Targeted research is being carried out into the storage of carbon dioxide in saline aquifers. These are saltwater-bearing layers that must lie at least 800 meters below the earth's surface in order for the pressure to be sufficient to keep the carbon dioxide in a liquid form. According to EnArgus, storage takes place through 3 mechanisms:

- The first is the displacement of water by carbon dioxide. At a depth of 800 meters, the ambient pressure is so great that the density of the carbon dioxide is approximately the same as that of the water. This allows the carbon dioxide to displace the surrounding water in the rock layers.
- The second mechanism is the dissolution of the carbon dioxide in the surrounding water, which takes several years to decades.
- The third mechanism is the conversion of carbon dioxide into carbonates, i.e., salts of carbonic acid. This process takes several thousand years.

Saline aquifers were formed 260 million years ago when the earth's crust in the north of what is now Central Europe subsided, creating a sea. Over the course of several million years, this has repeatedly dried out and been replenished. This created a salt layer measuring several kilometers which was covered with sediments over the following millions of years. One experimental facility worked in Germany from 2008 to 2013 in Ketzin. This facility stored about 67000 tons of carbon dioxide in a saline aquifer.
The advantage of using aquifers is that they have a very high storage capacity. Studies by the Geological Survey of Denmark and Greenland have estimated the total storage capacity of Europe's saline aquifers at 482 gigatons.[68]
However, many aquifers are not contiguous, so many boreholes would have to be created to fully utilize the capacities. The confining rock layer must also be completely impermeable to ensure that the carbon dioxide can escape. Another problem is the possible long transportation route due to the location of the aquifer, which brings its own problems. Transport needs its own infrastructure, for example in the form of pipelines. This also consumes a lot of resources and offers potential sources of defects.[69]

3.2.2 Oil and natural gas fields

According to the Geological Survey of Denmark and Greenland, there are 134 oil and gas fields in Europe that are suitable for storing carbon dioxide. The total capacity is estimated to be around 25 gigatons. So far there are facilities that inject the carbon dioxide into gas fields from Norway in the Baltic Sea. Example is given by the Norwegian gas fields called Sleipner

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[67] McGrath, Amanda/Jonker, Alexandra: Was ist Kohlendioxidabscheidung und -speicherung (CCS)?. 2024, https://www.ibm.com/de-de/think/topics/carbon-capture-storage.
[68] Anthonsen, Karen Lyng/Christensen, Niels Peter: EU Geological CO_2 storage summary. *DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT,* 34, 2021, https://cdn.catf.us/wp-content/uploads/2021/10/20183953/EU-CO2-storage-summary_GEUS-report-2021-34_Oct2021.pdf.
[69] Umweltbundesamt: Carbon Capture and Storage. 2024 https://www.umweltbundesamt.de/themen/wasser/gewaesser/grundwasser/nutzung-belastungen/carbon-capture-storage#grundlegende-informationen.

where Carbon dioxide has been injected 1 km below the seabed off the Norwegian coast since 1992. By 2019, 19 million tons of the gas are expected to have been injected.[70]
The technology does not differ significantly from that used in aquifers. One of the biggest advantages of decommissioned deposits is that they have been proven to be tight over long periods of time.[71] In contrast to the aquifers, it is certain that former oil and gas reservoirs are also suitable for the storage of carbon dioxide as they have held gases in the earth for millions of years.[72]

3.3 Risks

3.3.1 Leak proofness

The storage facilities must be absolutely leak-proof so that the gas cannot escape. According to an investigation by Monastersky a previously unknown layer of rock was discovered at the Sleipner facility through which carbon dioxide escapes from the storage facility into the surrounding rock.[73] According to a statement made by Greenpeace to the state parliament of Schleswig-Holstein, this makes a spill and contamination of the environment very likely.[74] Such a leak will drastically change the ecosystem on the sea floor and reduce biodiversity as the carbon dioxide displaces the oxygen and makes the water, in which it dissolves, more acidic.[75] Methane is already escaping from abandoned natural gas reservoirs from almost 50% of the wells analyzed. With over 15,000 boreholes in the North Sea there is therefore an increased risk that injected carbon dioxide could also escape from them.[76] However dangers exist not only during storage, but also during transport where the gas can escape into the atmosphere. Transport is to take place primarily via pipelines from carbon dioxide producers to intermediate storage facilities and final storage sites. This offers a number of potential sources of error that could also pose considerable risks to humans and animals. As carbon dioxide is denser than air and can collect on the ground, toxic gas bubbles can form. One example of this is a pipeline rupture in the state of Mississippi in the USA in 2020, which was triggered by a landslide. In this accident, 45 people had to be treated for asphyxiation symptoms.[77]

3.3.2 Seismic events

Natural earthquakes occur all the time in Europe. Fortunately, more severe ones are rare. The European Facilities for Earthquake Hazard and Risk (EFEHR) is a co-operation that researches earthquakes, provides hazard assessments and thus tries to prevent serious

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[70] Equionor: Sleipner area. https://www.equinor.com/energy/sleipner.
[71] Von Goerne, Gabriela/May, Franz: Wie sicher ist die CO2-Speicherung im geologischen Untergrund?. *https://www.bgr.bund.de/DE/Themen/Nutzung_tieferer_Untergrund_CO2Speicherung/CO2Speicherung/FAQ/faq_inhalt.html.*
[72] Gusterhuber, Jürgen/Abdank, Georg: Evaluierungsbericht der Bundesregierung. zum Bundesgesetz über das Verbot der geologischen Speicherung von Kohlenstoffdioxid, 2024, https://www.parlament.gv.at/dokument/XXVII/III/1210/imfname_1648931.pdf.
[73] Monastersky, Richard: Global carbon dioxide levels near worrisome milestone. *Nature,* 497, 2013.
[74] Smid, Karsten: Greenpeace Stellungnahme zu CCS. 2023, https://www.landtag.ltsh.de/infothek/wahl20/umdrucke/01200/umdruck-20-01231.pdf.
[75] Max-Planck-Gesellschaft: Kohlendioxid-Lecks am Meeresgrund vertreiben Tiere. Entweichendes Gas aus künstlichen Lagerstätten kann das Ökosystem massiv schädigen, 2018, https://www.mpg.de/11936761/kohlendioxid-ccs; BUND: Klimaschutz statt CO2-Endlager!. https://www.bund.net/klimawandel/ccs/.
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damage. According to their interactive earthquake risk map, the south-east of Europe in particular is at high risk of earthquakes, but there have also been stronger earthquakes in the north in the last thousand years. Even if they are rare, they are a danger that cannot be ruled out in the next 10,000 years.[78]
In addition to natural earthquakes, man-made earthquakes occur time and again. This usually occurs in connection with mining, oil and gas extraction, but also due to the injection of substances underground. The reason for this is pressure changes in deeper layers which cause tensions in the rock. These tensions can suddenly release and cause earthquakes of varying intensity. This does not necessarily have to happen during injection but can occur decades later.[79] The magnitude of such earthquakes caused by injections can vary. The strongest earthquake associated with injections in Europe had a magnitude of 4.5 on the Richter scale.[80] With a magnitude of 4.5 on the Richter scale, there is usually no damage, but these quakes can still be felt.[81] The consequences of such earthquakes depend heavily on the geological composition of the surrounding area. Theoretically, cracks can occur in the top layer of the repository through which the injected gas can escape. This happened in the storage facility of a carbon capture and storage plant in Algeria, although this had previously been ruled out. [82] However, there is very little data on the earthquake risk associated with the injection of carbon dioxide on land, as carbon capture and storage technologies are still very new. Simulations were carried out with different depths, pressures and surrounding rocks. This resulted in simulated earthquakes with a magnitude of 1.5 to 4.5 on the Richter scale. The risk of damage to human structures from induced earthquakes is therefore considered to be rather low.[83]

4. Hazard defense

To guarantee safety, the choice of location is crucial. On the one hand, the underground storage facilities must be at a great depth, be able to absorb carbon dioxide and ensure that no gas escapes through the cover layer. Long-term geological integrity must be guaranteed. Therefore, only areas that are far away from the continental plate boundaries but also from unstable zones in the continent can be considered. Conclusions can already be drawn today from the search for a final storage site for radioactive waste, as these should not only be safe for 10,000 years, but for a million years.[84] The methods for probing the deeper soil layers are constantly improving and conclusions can be drawn from existing rock layers in order to draw

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[78] European Facilities for Earthquake Hazard and Risk: EARTHQUAKES in Europe. http://www.efehr.org/start/.
[79] Healy, J.H./Rubey, W.W./Griggs, D.T./Raleigh, Cecil/ Bredehoeft, J.D.: The Denver Earthquakes. *SCIENCE*, 161, 1968, https://www.science.org/doi/10.1126/science.161.3848.1301.
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[81] Bormann, Peter: Was ist die Magnitude und was ist die Intensität eines Erdbebens?. http://bib.gfz-potsdam.de/pub/schule/magnitude_0209.pdf.
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[84] Kanitz, Steffen: Der Standort mit der bestmöglichen Sicherheit für 1 Million Jahre. https://www.unendlich-viel-energie.de/projekte/erneuerbar-statt-atomar/%E2%80%9Eder-standort-mit-der-bestmoeglichen-sicherheit-fuer-1-million-jahre%E2%80%9C.

trends for further geological development.[85] Technical safety during injection is the next critical factor. Decades of experience in oil and gas production and injection, such as in the Sleipner gas field, have already been gained in this area. However, there are always leakages either during transport, which, according to projections of natural gas transport, correspond to between 0.7 and 7.9 percent of the volume extracted.[86] To prevent gas escaping from underground, the injection hole must be completely sealed and strict monitoring must be carried out to continuously monitor the pressure in the storage facility and to observe whether the carbon dioxide continues to move underground. For monitoring deeper layers of the earth, there is the so-called 4D method, which is a combination of underground sensors with real-time data evaluation. Other supporting methods include satellite observation to detect ground heave or subsidence at an early stage. Satellite monitoring can also be used to detect atmospheric changes caused by escaping gases. Methods such as Distributed Acoustic Sensing Vertical Seismic Profiling are used to monitor the borehole during grouting. Glass fibre optic cables are installed in the borehole together with sensors to take measurements during the process.[87] To ensure strict monitoring, a legal framework must be established. In Europe, this is regulated by Directive 2009/31/EC of the European Union. It stipulates that operators of carbon capture and storage facilities must strictly monitor and regularly submit reports documenting the current status of the storage facility and any problems. This continues until the storage facility is closed and handed over to the responsible authority.[88] The problem here is human unreliability. To ensure strict monitoring, everyone must adhere strictly to the instructions.

4. Conclusion

According to the current state of knowledge, sites for the injection of carbon dioxide could be considered primarily in northern Europe, particularly in the North Sea. They must be located in geologically stable layers. Far away from the continental margins and known geologically active areas. Here, disused natural gas fields and oil fields that have proven their impermeability over geologically relevant periods of several million years are particularly suitable. Nevertheless, events such as the discovery of the migration of the injected gas in the Sleipner gas field have shown that the most precise research is necessary to ensure safety. Even though the methodology for underground exploration is constantly improving, there is currently no 100 per cent certainty that carbon dioxide reservoirs will be safe for tens of thousands of years.

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To what extent would the EU be able to defend its territory against external threats if NATO were significantly weakened by a U.S. withdrawal?
(Jonn Horstmann)

1. Introduction

With the war in Ukraine, land war has returned to Europe – the first major conflict of this kind on the continent since World War II. This conflict is currently the most significant geopolitical event in European politics.[89] Following the Cold War and the dissolution of the Soviet Union, many in the West believed long-term peace could be achieved through trade and diplomatic agreements with Russia. For over three decades, this belief guided European foreign policy. But Russia's full-scale invasion of Ukraine on February 24, 2022, breaked that illusion.[90]
The European Union responded with economic sanctions and military support for Ukraine. However, internal divisions soon became apparent. While countries like France and Germany supported arming Ukraine, others, including Hungary and Slovakia were sceptical. Even if all EU member states were as supportive as the Baltic countries, replacing the military support from the United States would still be extremely challenging.[91]
This is especially concerning given recent political developments in the U.S. With Donald Trump's return to the White House, American commitment to NATO has become uncertain. Statements by Trump, Secretary of State Marco Rubio, and Vice President J.D. Vance suggest that Europe must take greater responsibility for its defense and that negotiations with Russia might begin with concessions – actions that could weaken NATO's credibility.[92]
These changes make it essential for the EU to explore how it can strengthen its own defense capabilities and reduce dependency on the U.S.

2. Threat Situation

2.1 A potential attack by Russia on another European country

When Putin was asked what the worst catastrophe of the twentieth century was, Putin replied: the collapse of the Soviet Union.[93] He did not mention the First or Second World Wars, which would be understandable, as masses of Russians died in these wars. This, in combination with the repeated statements that he would protect Russian minorities in the Baltic states[94], leads experts to assume that Russia might attack another European state[95]. The major European states in particular, such as France and Germany, ignored the threat posed by Russia for a long time and only admitted after the full scale invasion in 2022 that mistakes had been made in Russia policy. The German Federal President Frank Walter Steinmeier also expressed self-criticism in retrospect and admitted that he had made mistakes, particularly in the Nord

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[92] Tagesschau. (2024, 12. Februar). *Trumps NATO-Äußerung sorgt auch in Deutschland für Diskussionen*. https://www.tagesschau.de/inland/deutschland-trump-aeusserung-nato-100.html.
[93] MDR. (n.d.). *Putin, Russland und die Sowjetunion: Geopolitik und Kriegshintergründe*. Abgerufen am 10. März 2025, von https://www.mdr.de/geschichte/zeitgeschichte-gegenwart/politik-gesellschaft/putin-russland-sowjetunion-geopolitik-krieg-hintergruende-100.html.
[94] Tagesschau. (n.d.). *Putin und Lettland: Geopolitische Spannungen*. Abgerufen am 10. März 2025, von https://www.tagesschau.de/ausland/putin-lettland-100.html.
[95] Deutschlandfunk. (n.d.). *Russland und die NATO: Kriegsgefahr*. Abgerufen am 10. März 2025, von https://www.deutschlandfunk.de/russland-nato-kriegsgefahr-100.html.

Stream 2 project, and had ignored warnings from Eastern European allies.[96] The Eastern European countries, especially Poland and the Baltic states, have seen their early warnings against a revanchist Russia since the Georgian war in 2008 and the annexation of Crimea in 2014 confirmed.[97]

2.1.1 Suwalki Gap

The Suwalki Gap is considered NATO's most vulnerable spot. It is a narrow strip of land about 65 kilometers long that connects Poland and Lithuania. On one end, it borders Belarus, and on the other, the Russian exclave of Kaliningrad. Since the war in Ukraine began, fears have been growing in the Baltic states that they might be next on Russia's list.[98]
Military experts are concerned that Russia could quickly move troops from both the east and west, taking control of the Suwalki Gap within 30 to 60 hours and cutting off the land connection. In that scenario, the Baltic states would be isolated from their NATO allies in Europe and could only be accessed via the Baltic Sea or by air.[99]
This makes the Suwalki Gap NATO's geographic weak point, where the risk of military escalation between Russia and NATO is at its highest. To strengthen defenses in the area, Germany's former defense minister, Boris Pistorius, sent a brigade of 5,000 soldiers to Lithuania.[100]
But even with this new realization, Europe is not yet safe from an attack on the Baltic states. Russia could see NATO and the EU as weakened, which is not only due to the possible withdrawal by the US from the alliance, but also due to several events in the past.[101]

2.2 The relatively weakness of NATO

After the end of the cold war, 16 more countries joined NATO, which made the defense alliance stronger.[102] But parallel to these objective numbers of members the subjective strength of NATO has decreased. This is not about the financial power or the number of members but more about the way NATO acted. In this context it is necessary to outline how NATO left Afghanistan without any achieved goal. Even the withdrawal from this country seemed to be chaotic and not well organized. That surprised experts and was a big win for the Talibans. Not only for them but also for other countries who are not in a good relationship with the west were observing the situation accurately, because the involved NATO members could not fulfill their own expectations. This geopolitical defeat left an image of an unorganized alliance.[103]

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[96] Die Zeit. (2022, 12. April). *Steinmeier räumt Fehler im Umgang mit Russland ein*. Abgerufen am 10. März 2025, von https://www.zeit.de/politik/deutschland/2022-04/frank-walter-steinmeier-fehler-russland-ukraine.
[97] Klein, M. (2022). *Russlands Krieg gegen die Ukraine: Auswirkungen auf die europäische Sicherheitsordnung* (CSS Analyse Nr. 306). ETH Zürich, Center for Security Studies (CSS). Abgerufen am 10. März 2025, von https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/549976/CSSAnalyse306-DE.pdf?sequence=2&isAllowed=y.
[98] MDR. (2023, 28. Juni). *Die Suwalki-Lücke: NATO-Schwachstelle zwischen Polen und Litauen*. Abgerufen am 10. März 2025, von https://www.mdr.de/nachrichten/welt/osteuropa/politik/suwalki-luecke-gap-ukraine-russland-belarus-krieg-nato-100.html.
[99] n-tv. (2023, 5. Juli). *Um diese Region sorgt sich die NATO am meisten*. Abgerufen am 10. März 2025, von https://www.n-tv.de/politik/Um-diese-Region-sorgt-sich-die-NATO-am-meisten-article24783116.html.
[100] Tagesschau. (2023, 26. Juni). *Pistorius zu Besuch in Litauen: Deutschlands Beitrag zur NATO-Ostflanke*. Abgerufen am 10. März 2025, von https://www.tagesschau.de/ausland/europa/litauen-pistorius-zu-besuch-100.html.
[101] Schmücking, D. (2021). *Afghanistan: Der Westen scheitert, China und Russland gewinnen*. Stiftung Wissenschaft und Politik (SWP). Abgerufen am 10. März 2025, von https://www.swp-berlin.org/publikation/afghanistan-der-westen-scheitert-china-und-russland-gewinnen.
[102] NATO. (n.d.). *Willkommen bei der NATO*. Abgerufen am 10. März 2025, von https://www.nato.int/nato-welcome/index_de.html.
[103] Schmücking, D. (2021). *Afghanistan: Der Westen scheitert, China und Russland gewinnen*. Stiftung Wissenschaft und Politik (SWP). Abgerufen am 10. März 2025, von https://www.swp-berlin.org/publikation/afghanistan-der-westen-scheitert-china-und-russland-gewinnen.

The relative weakness seems to be even bigger by looking at the war in the Ukraine. The war takes place in Europe, the continent where most of the ally members are located. Not only the fact that NATO could not prevent this war is a characteristic but also that since today the ally was not able to end this war. An ally with a GDR of 51 Trillion US Dollar is not able to stop an aggressor with a GDR of almost 2 Trillion US Dollar[104].
The relative weakness of NATO and the European Union could tempt Russia to launch a strike against NATO territory to test how united the alliance would react[105].

2.3 Hybrid war

Disinformation campaigns, fake news, and sabotage have been around as long as wars themselves. But with the rise of the internet, the amount and quality of disinformation in the 21st century have reached a whole new level.
Since Crimea was annexed in 2014, Putin has stepped up both the intensity and range of these disinformation efforts. Besides using traditional media like state-controlled TV and newspapers, Russia also relies on social media and messaging apps. These modern tools make it possible for the aggressor to spread propaganda directly to people in targeted countries.
And it seems to be working: There are several political parties within the EU that pick up on these Russian narratives, spreading them and causing unease among the public.[106]

While desinformation is used to influence society, sabotage is used to damage civil and military infrastructure. The advantage of acts of sabotage over a military attack is that they can cause damage to the other side at a much lower cost and it is not necessarily possible to trace who carried out the act. Even if states do not usually claim responsibility for these attacks, they want to ensure that the attacked country is afraid of them.
These acts of sabotage increased since the full scale invasion in Ukraine started. The best known recent sabotage actions are certainly the damage to several submarine cables in the Baltic Sea by ships of the Russian shadow fleet.[107] But the types of attacks are much more diverse: Two suspected Russian agents are on trial in Bavaria for allegedly planning attacks on military infrastructure[108]; German security authorities are warning of “unconventional incendiary devices” in parcels that could ignite if they are left in logistically sensitive freight centres[109]; Seven people are on trial in the UK for allegedly carrying out an attack on a Ukrainian company on behalf of Russia.
The advantage of this type of warfare is that you do not have to wait for a military conflict to significantly weaken your opponent. One single attack is not enough on their own to respond

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[104] Statista. (2023). *Bruttoinlandsprodukt (BIP) der NATO im Vergleich zur SOZ 2023*. Abgerufen am 10. März 2025, von https://de.statista.com/statistik/daten/studie/1002057/umfrage/vergleich-des-bruttoinlandsprodukt-bip-von-nato-und-soz/.
[105] BR. (2022, 3. März). *Will Russland wirklich ein NATO-Land angreifen? Weshalb Putin droht und warum die Politik warnt*. Abgerufen am 10. März 2025, von https://www.br.de/nachrichten/deutschland-welt/will-russland-wirklich-ein-nato-land-angreifen-weshalb-putin-droht-und-warum-die-politik-warnt,U3aTLz7.
[106] Goertz, S. (2023). *Hybride Bedrohungen und Desinformation: Herausforderungen für die Sicherheitspolitik*. SIAK-Journal – Zeitschrift für Polizeiwissenschaft und polizeiliche Praxis, 2/2023. Bundesministerium für Inneres (BMI), Österreich. Abgerufen am 10. März 2025, von https://www.bmi.gv.at/104/Wissenschaft_und_Forschung/SIAK-Journal/SIAK-Journal-Ausgaben/Jahrgang_2023/files/Goertz_2_2023.pdf.
[107] Tagesschau. (2023, 7. Juli). *Ostsee-Schutz vor Sabotage: Maßnahmen zur Sicherung der Infrastruktur*. Abgerufen am 10. März 2025, von https://www.tagesschau.de/inland/innenpolitik/ostsee-schutz-sabotage-100.html.
[108] Der Spiegel. (2025, 9. März). *Generalbundesanwalt ermittelt: Zwei mutmaßliche russische Saboteure in Bayern verhaftet*. Abgerufen am 10. März 2025, von https://www.spiegel.de/politik/deutschland/generalbundesanwalt-ermittelt-zwei-mutmassliche-russische-saboteure-in-bayern-verhaftet-a-0115bebd-195a-41fb-83be-da8d642045cd.
[109] Tagesschau. (2025, 8. März). *Warnung vor Brandsatz-Paketen: Behörden raten zur Vorsicht*. Abgerufen am 10. März 2025, von https://www.tagesschau.de/inland/warnung-brandsaetze-pakete-100.html.

with military countermeasures. This makes the situation so complex and requires the attacking side to be creative and not overreact. According to the diffuse conflict situation with Russia the German lieutenant general describes the situation with the words: “We are not at war, but we have not been at peace for a long time. We are in a phase in between.”

3. What political strategies have the European countries to minimize the threat

According to the mentionend threats it is necessary for the European states to react united on them. And since the help from the USA is not certain anymore it could be more urgent then ever before.

The European Union has to learn to speak with one voice since it establishes itself as a major player in global politics. This unity is essential for negotiating the best possible conditions in trade and security policies.[110] However, with 27 member states, it is never easy to agree on a single strategy for a specific issue. Foreign policy in particular is a major challenge. Leaders like Viktor Orban, the Prime Minister of Hungary, has a more pro-Russian position and are critical for supporting Ukraine.[111] Due to the EU's veto system these leaders can block military and financial aid to Ukraine.[112]

The NATO is since Trump is back in the White House also not united as before. A common strategy is missing. Furthermore, does every country have its own interests which leads to the problem that the allies have no common strategy.[113] To find a solution for the existing issues it can be helpful to find new allies, to expand the European nuclear umbrella or to talk about a European Army and ways to make the military armament more efficient.[114]

None of this is intended to replace NATO; it is and will remain a functioning alliance. But in order to be able to defend ourselves on our own if the worst comes to the worst, it is necessary to find a new common European strategy.[115]

In the area of defence procurement, there is currently insufficient cooperation between European countries.[116] For example: There are 11 different models of battle tank in use in the EU. In the USA there is only one model.[117] On the one hand, this plurality of different devices makes production more expensive than necessary, as lower quantities are more expensive to produce than high quantities. On the other hand, it makes the supply of spare parts more difficult.[118] Based on this, it is logical that the EU decided on a joint procurement programme

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[110] Heinemann, C. (2006, 23. Oktober). *Europa muss endlich lernen, mit einer Stimme zu sprechen*. Deutschlandfunk. https://www.deutschlandfunk.de/europa-muss-endlich-lernen-mit-einer-stimme-zu-sprechen-100.html.

[111] Deutsche Welle. (2025, 12. April). *Ungarn geht mit Riesenschritten in Richtung Russland*. https://www.dw.com/de/ungarn-geht-mit-riesenschritten-in-richtung-russland/a-71986927.

[112] Deutschlandfunk. (2025, 14. März). *EU verlängert Russland-Sanktionen – Ungarn nutzt Veto-Recht*. https://www.deutschlandfunk.de/eu-verlaengert-russland-sanktionen-ungarn-nutzt-veto-recht-100.html.

[113] Deutscher BundeswehrVerband. (2024, 7. Juli). *Verschiedene Interessen*. https://www.dbwv.de/aktuelle-themen/blickpunkt/beitrag/verschiedene-interessen DBwV+7DBwV+7DBwV+7.

[114] Bölükbasi, B. (2025, 19. März). *Wegen Trump-Rückzug aus Europa: NATO strebt nach EU-Türkei-Annäherung bei Verteidigung*. Merkur. https://www.merkur.de/politik/wegen-trump-rueckzug-aus-europa-nato-strebt-nach-eu-tuerkei-annaeherung-bei-verteidigung-zr-93620027.html&#8203.

[115] Fehrenbach, R., & Deißner, D. (2020, 11. März). *„Eine Europäische Armee kann die NATO ergänzen – aber nie ersetzen“: Ein Gespräch mit Hans-Peter Bartels, Wehrbeauftragter des Deutschen Bundestages*. Atlantik-Brücke. https://www.atlantik-bruecke.org/eine-europaeische-armee-kann-die-nato-ergaenzen-aber-nie-ersetzen/.

[116] Deutschlandfunk. (2025, 28. Januar). *Aufrüstung der EU: Handlungsbedarf und viele Probleme*. https://www.deutschlandfunk.de/nato-europa-verteidigung-ausgaben-100.html.

[117] Europäische Sicherheit & Technik. (2019, 13. Dezember). *Das „Märchen“ der 17 EU Kampfpanzer*. https://esut.de/2019/12/meldungen/ruestung2/17331/das-maerchen-der-17-eu-kampfpanzer/.

[118] Tagesschau. (2024, 15. Juli). *Verteidigungsfähigkeit der EU: Zu viele Einzellösungen*. https://www.tagesschau.de/ausland/europa/eu-verteidigung-usa-100.html&#8203.

worth 300 million euros in November 2024.[119] The next important step with a signal effect was the announcement from von der Leyen to invest 800 billion euros in Europe's security over the next few years. This figure should act as a deterrent to Putin, but this announcement must now also be put into practice in order for it to result in a real advantage for Europe.[120]

4. What military power can the European countries provide to minimize the threat

Despite its fragmented military structure, the European Union collectively possesses a strong defense capacity – one that, if better coordinated, could become a reliable alternative or complement to NATO's traditional role.

The EU member states combined spend over 350 billion euros annually on defense. While this figure surpasses Russia's military budget by a wide margin, these resources remain underutilized due to duplication, inefficiencies, and lack of interoperability between member states.[121]

France plays a critical role in Europe's security. As the only nuclear power in the EU and a permanent member of the UN Security Council, France has global military reach.[122] It maintains an operational aircraft carrier, a nuclear triad, and one of the most professional and experienced armed forces in Europe. French forces are active in several regions, from the Sahel to Eastern Europe, showing a consistent commitment to international security.[123]

Germany, who misses long time the 2% target, has begun a major overhaul of its defense policy. The "Zeitenwende" – announced by Chancellor Olaf Scholz in 2022 – promised 100 billion euros in new military investments. Germany has also agreed to permanently station troops in Lithuania and is rebuilding its armored forces and air capabilities. While progress has been uneven, Berlin's increased focus on defense is a significant shift in European security policy.[124]

Poland is emerging as a military heavyweight in Central and Eastern Europe. It has rapidly increased its defense spending and is modernizing its military with advanced equipment from both the U.S. and South Korea. Warsaw aims to field one of the largest land forces in Europe.[125]

Additionally, several EU countries participate in multinational projects like the European Sky Shield Initiative, the Future Combat Air System (FCAS), and the Main Ground Combat System (MGCS). These projects aim to standardize and integrate European defense technologies.

Cyber defense and space capabilities are also growing in importance. The European Union Agency for Cybersecurity (ENISA) is working to enhance Europe's resilience against digital threats. Meanwhile, the EU's space program – especially with the Galileo satellite network – provides strategic autonomy in navigation and communications.

However, weaknesses remain. Logistics, command structures, and rapid deployment mechanisms need urgent improvement. EU Battlegroups, once intended to be quickly

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[119] EUROPE DIRECT Dresden. (2024, 5. Dezember). *Was ist passiert in der EU? Der Rückblick: November 2024*. https://europa-in-dresden.de/2024/12/05/was-ist-passiert-in-der-eu-der-rueckblick-november-2024/&#8203.

[120] Von der Leyen, U. (2025, 14. März). *Erklärung von Präsidentin von der Leyen zur Einigung über das 13. Sanktionspaket gegen Russland*. Europäische Kommission. https://ec.europa.eu/commission/presscorner/detail/de/statement_25_673.

[121] Aschoff, D., & Fabian, P. (2025, März 4). Überzahl gegen Putin: Wie stark sind Europas Armeen? *BILD*. https://www.bild.de/politik/ausland-und-internationales/ueberzahl-gegen-putin-wie-stark-sind-europas-armeen-67c57a46f0c49c5db213de40.

[122] Statista. (2024). *Anzahl der Atomsprengköpfe nach Ländern weltweit im Jahr 2024*. https://de.statista.com/statistik/daten/studie/36401/umfrage/anzahl-der-atomsprengkoepfe-weltweit/.

[123] Statista Research Department. (2024, 6. März). *Militärische Stärke von Frankreich 2024*. Statista. Abgerufen am 13. April 2025, von https://de.statista.com/statistik/daten/studie/1333627/umfrage/militaerische-staerke-von-frankreich/.

[124] Friedrich-Ebert-Stiftung. (o. J.). *Zeitenwende: Sicherheits- & Außenpolitik im Wandel*. Abgerufen am 13. April 2025, von https://www.fes.de/wissen/zeitenwende.

[125] SRF News. (2025, 11. März). *Kriegsangst in Warschau: Polen rüstet sich für einen russischen Angriff*. Schweizer Radio und Fernsehen. Abgerufen am 13. April 2025, von https://www.srf.ch/news/international/kriegsangst-in-warschau-polen-ruestet-sich-fuer-einen-russischen-angriff.

deployable military units, have never been used in a real mission. Command and control structures remain national rather than European, making joint operations complex and slow to organize.[126]
To counter these shortcomings, deeper cooperation under initiatives like PESCO (Permanent Structured Cooperation) and the European Defence Fund is crucial. These programs aim to streamline defense spending, promote joint procurement, and reduce fragmentation.[127]
With the right political momentum, improved interoperability, and strategic vision, the EU could evolve into a powerful and self-reliant military actor. This would require long-term investment and political will – but the potential already exists.

5. Conclusion

The return of war to Europe and the uncertainty of continued American leadership in NATO have forced the EU to reconsider its defense capabilities. As it stands, the EU is not yet ready to defend itself entirely without NATO – especially without U.S. involvement.[128]
While the EU has economic strength, political will, and a large population, its military capacities remain divided and underutilized. Internal disagreements, slow decision-making, and fragmented equipment hinder its ability to respond effectively to external threats.
The EU is taking steps in the right direction. Increased defense spending, procurement reforms, and political discussions about strategic autonomy suggest that Europe is beginning to take its security more seriously.[129]
So, to answer the question – To what extent would the EU be able to defend its territory against external threats if NATO were significantly weakened by a U.S. withdrawal?
In the short term, the EU would struggle to defend its territory without U.S. support. But with continued investment, improved coordination, and stronger political unity, the EU could gradually build a more independent and capable defense system.
Europe must act now to ensure it is prepared – not just to support NATO, but to stand on its own if necessary.

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[126] Schmuck, O., & Unser, G. (2018). *Die Europäische Union: Aufgaben, Strukturen und Chancen*. Bundeszentrale für politische Bildung.
[127] Wagner, J. (2019). *PESCO: Das militaristische Herz der Europäischen Verteidigungsunion*. In Ö. A. Demirel (Hrsg.), *Europäische Studien zur Außen- und Friedenspolitik* (Nr. 1). Abgerufen am 13. April 2025, von https://oezlem-alev-demirel.de/wp-content/uploads/2023/06/PESCO-Broschuere.pdf.
[128] Schmidt, H. (2025, 19. Februar). *Sicherheitspolitik ohne die USA: Europa kann sich selbst verteidigen*. Tagesschau. Abgerufen am 13. April 2025, von https://www.tagesschau.de/kommentar/europa-usa-sicherheitspolitik-100.html&#8203.
[129] Info-Point Europa. (2025, 4. März). *ReArm-Europe-Plan zur Aufrüstung Europas.* Abgerufen am 13. April 2025, von https://infopoint-europa.de/de/articles/rearm-europe.

Light pollution

What methods can be used to reduce the negative effects of light pollution on moths in Germany?

(Talika Kolboom)

1. Introduction

The global extinction of species – not least due to anthropological climate change – is also noticeable in Germany and the light pollution plays a major role. Nocturnal invertebrates such as moths are particularly affected. While soil, water and air pollution are familiar to most people, light pollution is unjustifiably little known, although the annual increase in Germany is about 6%. (Ecology and Society: The Dark Side of Light: A Transdisciplinary Research Agenda for Light Pollution Policy)

This article examines the various approaches to reducing light pollution for the benefit of moths. The aim is to answer the question "How can Germany reduce the negative effects of light pollution on moths?" by comparing possible solutions. The focus is on weighting up the realistic feasibility, the effectiveness and the associated costs.

Based on my research, it can be said that legal regulations on temporal and spatial restrictions on public lighting in combination with technical optimization of lighting systems is the most promising solution from an ecological and economic point of view. It is important that these measures are implemented at federal level.

2.1 Definition of light pollution

It is important to understand in advance what light pollution is, in order to understand the problem that this paper deals with. Therefore, the definition is the first point.

Light pollution is a form of environmental pollution. Artificial light sources ensure a permanent absence of complete darkness. The main problem is light sources that shine upwards, while the light is scattered in the air layers of the atmosphere, where it is reflected by the water droplets and overlays the natural darkness. This process is called light emission, and it occurs especially in large cities with its excessive light emission caused by street lighting, advertising signs and industrial lighting.

Lighting in public spaces follows two basic principles. On the one hand, there is the aspect of safety (§ 32a StVO). In traffic, sufficient visibility must be guaranteed even at night in order to minimize the risk of accidents. On the other hand, there are also lightings that exist only for aesthetic purposes, like the lighting of sights, for example. (Port of Hamburg | Speicherstadt leuchtet seit 20 Jahren).

2.2 History of light pollution

Since Edison invented the light bulb during the industrialization of the 19th century, electric light has been used more and more in private and public spaces. From 1901 onwards, gas lamps were gradually replaced by electric street lamps. In 1930, about 20% of Berlin’s street lamps were electric. The first illuminated advertising signs appeared in 1896, initially powered by light bulbs and later by neon tubes. Berlin was named the "capital of light" and was considered as the center of light bulb production until the World War II. At about the same time, the first neon signs were used. Initially they were powered by light bulbs, later by neon tubes invented by George Claude in 1909. Especially in the “Golden Twenties”, numerous illuminated signs characterized the streets of major cities. The switch from conventional light bulbs to brighter modern LED technology was made for reasons of energy efficiency. However, the use of LEDs has changed the color spectrum of nighttime lighting: the proportion of blue light has increased.

2.3 Lifestyle of moths

Butterflies are divided into day and night butterflies. The latter make up the majority at around 95%. Moths are invertebrates that are primarily active at dusk and at night. This way of life has the advantage that they have fewer predators and competitors to fear for food, as many of them are active during the day. In contrast to the mostly colorful butterflies, moths are often inconspicuous in their appearance. This means that they are well camouflaged in their hiding places during the day. In order to attract sexual partners for reproduction, moths do not need a magnificent appearance, as the females attract the males using pheromones. Since moths have highly developed senses, they can detect these sexual attractants even from many kilometers away with their sensitive antennae. After reproduction, the female lays her eggs on the underside of the leaves of selected plants. The caterpillars that hatch from the eggs depend on certain plants. As soon as they hatch, they immediately start eating. They consume large quantities of plants within a very short time. They grow quickly and shed their skin several times. Once they have stored enough energy, they pupate in a cocoon. In this cocoon, the caterpillar transforms into a moth. The duration of this metamorphosis varies depending on the species and depends on external environmental influences. As hatched moths, they set off to reproduce. Their food source is the nectar of night-blooming plants. In this respect, moths are usually less specialized than when they were caterpillars. Moths play an important role as pollinators. When collecting nectar, their hairy bodies allow them to absorb a lot of pollen, which they transport from one plant to the next. In this way they ensure the survival of this plant species. They also have an important function as prey within the food chain. Their main predators, bats, depend on moths as a source of food. In addition, the moth caterpillars are valued by numerous bird species as a protein-rich food. Unfortunately, moths are under severe threat. Man-made climate change, intensive agriculture and the loss of habitat areas are affecting the biodiversity of moths. In Baden-Württemberg, an average decline of 21% has been observed since 2001 (Quelle: Nachtfalter-Monitoring). Due to the direct connection (predator-prey relationship), this has far-reaching effects on bats as well. A living creature can never be considered in isolation, because every animal is part of a closely interconnected system.

Another reason for the extinction of moth species is the increase in light pollution. Artificial light affects the animals in many ways. On the one hand, their biorhythm is disturbed because they orient themselves according to the length of the day. This disruption can be fatal, especially in the cold season. The moths overwinter as pupae in a dormant mode, called diapause. To survive the low temperatures, they slow down their metabolism in order to get by with as little energy as possible. Long, dark nights are needed to induce this state. If the nights are not dark enough due to light pollution, the moths cannot switch to the obligatory diapause. Instead, they often develop directly from the pupa to the moth, hatch far too early and are exposed to the cold winter temperatures. Because the animals are very sensitive to temperature, they die.

Another problem is the irritation of the adult moths. When flying, they orient themselves using the moon as a fixed point on the horizon and thus acts as a kind of compass. Artificial light sources that emit bright scattered light compete with the moon and mistakenly attract moths. Disoriented, they fly into the beam of light from street lamps, for example, and cannot find their way out. Instead, they swarm around in the light until they are exhausted and usually die. They are also easy prey for predators. It is noticeable that moths do not react to all light in the same way. Only short-wave, blue light attracts the animals. This is because moonlight has a similar wavelength.

2.4 Legal regulations

To reduce light pollution in public spaces, more action is needed at the legislative level. There is no law in Germany that directly aims to combat light pollution. Provisions of the Federal Nature Conservation Act (BNatSchG), the Federal Emissions Act (BImSchG), the Building Code (BauGB), and the Building Use Ordinance (BauNVO) have an indirect impact.

The Federal Nature Conservation Act (BNatSchG) is the legal basis for nature and landscape and corresponding measures to protect these assets. This law was adapted to combat light pollution. The amended federal law came into force on March 1, 2022. Section 23, Paragraph 4

is new: "In nature conservation areas, the construction of new lighting on streets and paths, as well as illuminated or light-emitting advertising structures, is prohibited in outdoor areas in accordance with Section 35 of the Building Code (BauGB). An exception to the prohibition in sentence 1 may be granted upon request, provided that
1. the protective purposes of the area cannot be compromised, or
2. this is necessary for reasons of traffic safety or other public safety interests. Further protective provisions, in particular [...] under state law, remain unaffected."

Amended regulations also apply to municipal street lighting. Section 41a was newly added to the Federal Nature Conservation Act (BNatSchG). Accordingly, newly constructed lighting on streets and paths, exterior lighting of buildings and properties, and illuminated or light-emitting advertising installations must be technically and structurally installed, equipped with lamps, and operated in such a way that animals and plants of wild species are protected from adverse effects caused by light emissions, which must be avoided in accordance with a legal ordinance pursuant to Section 54 Paragraph 4d Numbers 1 and 2. Sentence 1 also applies to significant changes to the lighting of streets and paths, buildings and properties, and advertising installations mentioned therein. Existing lighting on public roads and paths must be converted or retrofitted in accordance with a legal ordinance pursuant to Section 54 Paragraph 4d Number 3 (Section 41a of the Federal Nature Conservation Act). The exact requirements for street lighting to protect animals and plants are not yet known. At the state level, progress has already been made in this regard. The State Nature Conservation Act of the federal state of Baden-Württemberg, for example, contains the regulation that the lighting of the facades of buildings in public spaces is prohibited all day from April to September. Furthermore, this lighting may only be operated from 6 a.m. to 10 p.m. from October to March. Exceptions are only permitted for reasons of public safety. A similar provision can be found in the Bavarian Nature Conservation Act: "Interference with insect fauna through artificial lighting in outdoor areas must be avoided. Skylights and devices with similar effects are prohibited. When installing lighting systems in outdoor areas, the effects on insect fauna, in particular their impairment and damage, must be assessed, and the objectives of species protection must be taken into account. Lighting in the immediate vicinity of protected landscape elements and biotopes shall only be approved by the competent authority or with its consent in exceptional cases."
These regulations at the state level may be an indication of the more detailed regulations still pending for Section 41a of the Federal Nature Conservation Act (BNatSchG). A time limit on lighting in public spaces is therefore highly likely.
The Federal Immission Control Act (BImSchG) serves to protect people, animals, and plants from harmful environmental impacts. According to Section 3, Paragraphs 2 and 3, light is also considered to be a relevant element if there is a significant danger to the public pursuant to Section 3, Paragraph 1. Facilities must be constructed in such a way that they do not result in harmful environmental impacts (Section 5, Paragraph 1, Section 22, Paragraph 1). The federal states' emission control laws often go even further than the Federal Immission Control Act. Bavaria is once again setting a good example here: According to Article 9, it is prohibited to illuminate the facades of buildings in public spaces after 11 p.m. until dawn. Exceptions exist if the lighting is essential for reasons of public safety or is required by law.
Section 9, paragraph 24 of the Federal Building Code (BauGB) states that municipalities can designate areas for special facilities and precautions to protect against harmful environmental impacts within the meaning of the Federal Immission Control Act (BImSchG) in their development plans. According to Section 15, paragraph 1, sentence 2 of the Federal Immission Control Act (BauNVO), facilities are prohibited if they cause unreasonable nuisances, such as strong light emissions.

2.5 Technical solutions
In addition to the legal level, there are already good technical innovations that can reduce light pollution and its negative effects on moths. Two options are distinguished: the production of new moth-friendly lighting systems and the retrofitting of existing ones. In both cases, the choice of light source is crucial. As described at the beginning, the moths are primarily attracted

to blue light. This can be achieved by using light sources with a spectral range of at least 500 nm.

Fostering International Relations: An In-Depth Analysis of the Impact of Democracy and Autocracy on Global Engagement and Development

What is the impact of governance type – democracy versus autocracy – on a nation´s ability to form international alliances and achieve economic growth?

(Enock Ofosuhene)

1. Introduction

A country's political system – whether democratic or autocratic – has a major influence on how it develops and interacts with the rest of the world. This study looks at two very different countries: Germany, a democracy, and North Korea, an autocracy. It explores how their forms of government shape their international relationships and economic growth. Germany works closely with other countries through trade and alliances, while North Korea is more isolated and faces strict international sanctions.

In global politics, protecting national interests is essential for a country's survival and progress. This idea has guided international relations for centuries, especially since the Peace of Westphalia in 1648, which established the importance of national borders and state independence. Today, groups like NATO, the EU, and BRICS show how countries work together – or remain apart – depending on how they are governed.

By comparing Germany and North Korea, this thesis reveals how different systems of government impact a country's place in the world.[130]

2. Theoretical Framework

Democracy (Greek: demokratia—from demos (people) and kratos (rule)) is defined by Abraham Lincoln as "a government of the people, by the people, and for the people." It is characterized by political participation, institutional representation (such as parliaments), and electoral processes that empower citizens to shape governance (Britannica: The Theory of Democracy).

Autocracy, by contrast, centralizes power, suppresses dissent, and restricts political pluralism. It relies on absolute authority, state control over institutions, and the repression of individual freedoms (Easysociology: An Outline and Explanation in Sociology).

These two governance models profoundly shape domestic policies, civil liberties, and international engagement.

2.1 Germany: A Democratic Paradigm

Historical Evolution of Germany's Democratic Institutions:

Germany's transformation into a stable democratic state is the result of a turbulent yet instructive historical journey. Having experienced imperial rule, totalitarianism under the Nazi regime, and the collapse of the Weimar Republic, Germany's modern democracy emerged from the ruins of World War II. The pivotal moment in this transition came in 1949 with the adoption of the Grundgesetz (Basic Law), originally intended as a provisional constitution for West Germany.

Crafted in Bonn, the Basic Law was designed to prevent the constitutional weaknesses that contributed to the fall of the Weimar Republic and the rise of Hitler. Key safeguards were

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[130] Manual für Human Rights for Young People: what is Democracy:
https://www.coe.int/en/web/compass/democracy
Historical development of Germany's Democracy-
https://www.bundestag.de/en/parliament/history/parliamentarism/gdr/gdr-200348
https://www.coe.int/en/web/compass/democracy.

introduced, including a constructive vote of no confidence – allowing the Bundestag to remove a chancellor only if a successor is elected simultaneously – to ensure political stability. Following the reunification of East and West Germany in 1990, the Basic Law was affirmed as the official constitution of a united Germany (Bundeszentrale für politische Bildung – bpb.de).
The Basic Law established a parliamentary democracy, in which the executive is derived from and accountable to the legislature. Power is shared among key institutions:
The Bundestag (lower house of Parliament), directly elected by the people.
The Bundesrat (upper house), representing the federal states.
The Federal Chancellor, who serves as head of government.
The Federal President, a largely ceremonial head of state who ensures constitutional adherence.
A cornerstone of Germany's democratic framework is the protection of fundamental rights (Grundrechte), which are enshrined in the first 20 articles of the Basic Law. These include:
Freedom of speech and assembly, Freedom of religion and belief, The right to vote and stand for public office Human dignity as inviolable (Article 1).
These rights are not only protected but also actively defended. The state has the legal authority to ban organizations and political parties that threaten the democratic order, as demonstrated in historical bans on neo-Nazi and extremist groups (Federal Constitutional Court rulings).
Germany's post-war democratic development has become a model for liberal democracy, [131] emphasizing federalism, rule of law, and human rights. As noted by Deutschland.de, [132] "Germany's democracy is based on the values of liberty, equality, and solidarity," and it continues to promote these values both domestically and through its foreign policy initiatives.

Impact of democratic governance on Germany's foreign policy
Democratic countries often align themselves with others that share similar political values, and Germany is no exception. As a central member of the European Union and a global advocate for democracy and human rights, Germany's foreign policy is strongly influenced by its commitment to liberal democratic principles. This shapes how it engages with other countries, favoring close cooperation with democratic nations and maintaining a cautious or critical stance toward authoritarian regimes.

Germany maintains strong diplomatic and economic ties with democratic countries such as the United States, Canada, and the United Kingdom. These relationships are built on shared values such as rule of law, transparency, and respect for human rights. In contrast, Germany's interactions with autocratic states like North Korea, Iran, Russia, and China are more complex and often marked by criticism over human rights concerns and political repression.

For example, according to the Federal Foreign Office of Germany, the country holds no formal diplomatic relations with North Korea. This is due to North Korea's nuclear weapons program, its authoritarian government, and severe human rights violations. Germany supports international sanctions and only engages with North Korea through limited humanitarian aid.

Germany's relationship with China is more nuanced. China is one of Germany's largest trading partners, especially in sectors like automotive and manufacturing. However, political tensions exist. Germany has publicly expressed concern over human rights abuses in Xinjiang and the erosion of democratic freedoms in Hong Kong. The German government walks a fine line – pursuing economic cooperation while also supporting EU-wide efforts to address human rights violations and assert democratic values.[133]

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[131] Government and Society: Britannica:https://www.britannica.com/place/Germany/Government-and-society.
[132] Germany's Journey to Democracy:https://www.deutschland.de/en/topic/politics/st-pauls-church-in-frankfurt-i-the-history-of-german-democracy
https://www.coe.int/en/web/compass/democracy.
[133] living in in Germany:https://www.make-it-in-germany.com/en/living-in-germany/discover-germany/politics-democracy-freedom.

134

Similarly, Germany has sharply criticized Russia's invasion of Ukraine and has joined EU sanctions while reducing energy dependence on Russian gas. Its relationship with Iran is shaped by efforts to revive the nuclear agreement (JCPOA) while simultaneously condemning Iran's domestic repression and regional aggression.

In all cases, Germany's democratic identity and values play a key role in shaping its foreign policy, balancing strategic interests with a clear commitment to human rights, international law, and multilateral diplomacy.

Analysis of Germany's Economic Model and Its Correlation with Democratic Principles
Germany's economic model is deeply intertwined with its democratic values, reflected in its status as a Sozialstaat (social state) as enshrined in Article 20 of the German Basic Law (Grundgesetz). This concept promotes social justice, equal opportunity, and the protection of human dignity – core principles of democracy. The country follows a social market economy, a system that combines free-market capitalism with strong social policies to ensure economic efficiency, social welfare, and public accountability.

Germany's economy places significant emphasis on export-driven manufacturing, environmental responsibility, labor protections, and fair trade. It promotes workers' rights through collective bargaining, codetermination laws (Mitbestimmung), and strict labor standards. According to the Federal Ministry for Economic Affairs and Climate Action, this model encourages stable employment, wage equality, and cooperative economic development, which align with democratic ideals of inclusivity, transparency, and participation.

Germany's democratic nature means that public opinion often plays a crucial role in shaping economic decisions. A clear example occurred during the early stages of the Russia-Ukraine war in 2022. Germany faced heavy criticism – especially from its own citizens and EU partners – for continuing to import Russian gas despite growing evidence of Russian aggression. Public backlash and democratic debate eventually pushed the government to reduce its dependency on Russian energy, leading to a major shift in energy policy. In response, Germany accelerated investments in renewable energy and LNG infrastructure, aligning its economic practices with both democratic accountability and foreign policy goals (DW News, 2022; Bundesministerium für Wirtschaft und Klimaschutz).

Germany's commitment to fair trade and ethical labor practices also influences its international trade partnerships. It avoids engaging in trade agreements with countries known for severe labor abuses or forced labor. For example, Germany has supported EU sanctions and trade restrictions against nations that violate international labor standards or commit human rights abuses. This includes its critical stance on China's treatment of Uyghur Muslims in Xinjiang, which has prompted calls for import bans on products linked to forced labor (European Parliament Resolution 2022/2581(RSP)).

Moreover, Germany is a strong advocate for sustainable and equitable global trade through institutions like the World Trade Organization (WTO) and the International Labour Organization (ILO). Its trade policy reflects democratic values by emphasizing rule-based international cooperation, environmental protection, and human rights.

In conclusion, Germany's economic model – built on social market principles – reinforces its democratic identity. Its policies favor economic justice, social cohesion, and ethical global

[134] Germany-Russia Bilateral Relations:https://www.auswaertiges-amt.de/en/aussenpolitik/laenderinformationen/russischefoederation-node/russianfederation-218616.

engagement, reflecting the values of its democratic constitution and citizen-driven political culture.[135]

2.2 North Korea: Autocratic Regime

Historical Development of North Korea's Autocratic System

North Korea's autocratic regime emerged from the geopolitical aftermath of World War II. Following Japan's surrender in 1945, the Korean Peninsula was divided along the 38th parallel, with the Soviet Union occupying the North and the United States the South. Under Soviet influence, Kim Il-Sung, a former anti-Japanese guerrilla and Soviet military officer, was installed as the leader of North Korea in 1948. He soon established the Democratic People's Republic of Korea (DPRK), laying the foundations for a highly centralized, authoritarian state.

Initially modeled on Marxist-Leninist principles, North Korea's system evolved into a unique form of dynastic totalitarianism, heavily shaped by Juche, an ideology introduced by Kim Il-Sung that emphasizes self-reliance, nationalism, and absolute loyalty to the supreme leader. Over time, Juche replaced traditional communist doctrine, and the regime increasingly revolved around the cult of personality surrounding the Kim family. This system was later expanded with Songun ("military-first policy") under Kim Jong-Il, prioritizing the military as the core institution of the state.

The regime's grip on power has been maintained through a combination of strict surveillance, ideological indoctrination, internal purges, and the Songbun system, a hereditary social classification structure that determines individuals' access to resources, education, and employment based on perceived loyalty to the regime (HRNK – Committee for Human Rights in North Korea).

Under Kim Jong-Il and later Kim Jong-Un, the regime adapted to severe challenges, including economic collapse in the 1990s, international sanctions, and diplomatic isolation. North Korea pursued nuclear weapons as both a strategic deterrent and a tool for regime legitimacy, further deepening its rift with the global community. Despite recurring food shortages and growing international pressure, the regime has remained intact, reinforced by Confucian-inspired hierarchy, Stalinist control mechanisms, and nationalist propaganda that portrays the Kims as guardians of the Korean nation.

North Korea's governance today remains one of the most closed and repressive in the world. Freedom of expression, movement, and assembly are virtually nonexistent, and the regime tolerates no dissent. According to Freedom House and Amnesty International, North Korea scores among the lowest globally in terms of political rights and civil liberties, with widespread reports of labor camps, extrajudicial executions, and systemic human rights abuses.

This enduring autocratic structure reflects a complex blend of ideological rigidity, military dominance, and dynastic rule, sustained through a mix of coercion, propaganda, and strict social control – defining North Korea's place as one of the most extreme examples of modern authoritarianism.

2.3 Influence of Autocracy on North Korea's Foreign Relations and Strategic Partnerships

North Korea's autocratic structure profoundly limits its engagement with the international community. Its pursuit of nuclear dominance, centralized leadership under the Kim dynasty, and systemic human rights abuses have led to diplomatic isolation and heavy sanctions,

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[135] Federal Foreign Office of Germany – Country profiles and foreign policy documents: auswaertiges-amt.de
EU External Action Service (EEAS) statements on China, Russia, and Iran.
UN reports on humanitarian aid and human rights practices.

particularly from Western democracies like the United States and members of the European Union.

Strategic Alliances: China and Russia
Despite international isolation, North Korea maintains strategic partnerships with China and Russia, both of which serve as critical economic and political lifelines. China, North Korea's oldest and most significant ally since the Korean War, remains its largest trading partner, providing vital aid, fuel, and food. The 1961 Treaty of Friendship, Cooperation, and Mutual Assistance solidified a relationship that continues today, marked by regular high-level exchanges and mutual interest in regional stability (China-DPRK Relations Overview – Chinese Embassy in Pyongyang).

Similarly, Russia has deepened its partnership with North Korea, especially since its invasion of Ukraine in 2022. Reports suggest that North Korea has supplied Russia with munitions, possibly in exchange for advanced military technology and diplomatic backing in the UN Security Council (Arms Control Association, 2024; 38 North, 2024). In July 2024, the two [136] nations reportedly signed a military cooperation agreement, raising serious international concern (Arms Control Association, 2024).

Limited Engagement with Democratic Nations
North Korea's relationships with democratic nations are minimal or hostile. The United States and North Korea do not have formal diplomatic ties. Since the Korean War, the U.S. has imposed a near-total economic embargo, strengthened by United Nations sanctions in response to North Korea's weapons programs. While Sweden acts as a protecting power for limited U.S. consular services in North Korea, direct engagement remains rare and focused on crisis management (U.S. State Department).

The European Union adopts a policy of "critical engagement" with North Korea, aimed at reducing tensions, promoting denuclearization, and addressing human rights concerns. While the EU maintains limited humanitarian assistance, trade is minimal due to North Korea's non-membership in the WTO and disqualification from GSP benefits (European External Action Service). Human rights violations continue to be raised in bilateral dialogues and multilateral forums, including the UN Human Rights Council.

Germany's Diplomatic Approach
As part of the EU and a strong democracy, Germany does not maintain formal diplomatic relations with North Korea. According to the German Federal Foreign Office, Germany closed its embassy in Pyongyang in 2020, and maintains only humanitarian assistance where necessary. Germany supports diplomatic efforts aimed at denuclearization, human rights, and peaceful reunification of the Korean Peninsula (Auswärtiges Amt).

Conversely, Germany enjoys a close and cooperative relationship with South Korea, based on shared democratic values, trade, and cultural exchange. In 2023, the two nations celebrated 140 years of diplomatic ties, with Germany being South Korea's top trading partner in Europe (German Federal Foreign Office).

Inter-Korean Relations and Peace Efforts
Despite North Korea's hostile posture, South Korea has pursued diplomatic overtures aimed at peace and reunification. The 2018 Inter-Korean Summits led to the Panmunjeom

[136] https://www.freiheit.org/new-ties-between-north-korea-and-russia
https://www.international.gc.ca/country-pays/democratic_peoples_republic_korea-republique_populaire_democratique_coree/relations.aspx?lang=eng
https://www.auswaertiges-amt.de/en/aussenpolitik/laenderinformationen/koreademokratischevolksrepublik-node/bilateral-relations-229514.

Declaration, which envisioned the end of hostilities and greater economic and cultural cooperation. However, progress has been slow due to North Korea's resumed weapons testing and the closure of cooperative ventures like the Kaesong Industrial Complex (Ministry of Unification, South Korea).

President Yoon Suk Yeol's "audacious initiative" in recent years proposed economic aid to North Korea in exchange for denuclearization steps. While dialogue efforts have stalled, South Korea continues to support peaceful engagement within the framework of international sanctions (Unification Ministry of South Korea)

2.4 Internal Policies and Their Impact on Foreign Relations: Juche, Militarization, and Economic Strategy

North Korea's domestic policies, centered around the Juche ideology and a command economy, significantly shape its foreign relations. These policies reinforce a cycle of isolation, aggressive posturing, and dependence on a limited number of allies, while deterring meaningful integration with the global community.

1. Isolation and Self-Reliance (Juche Ideology)

Impact: Juche, the state's founding ideology, emphasizes absolute self-reliance, discouraging foreign influence and economic integration. This results in a deeply entrenched suspicion of international cooperation.

Relations: North Korea minimizes diplomatic and trade ties, prioritizing sovereignty over engagement. This excludes it from institutions like the World Trade Organization (WTO) and deters foreign direct investment.

Example: Unlike China or Vietnam, North Korea has resisted market-oriented reforms, keeping its economy isolated and limiting alliances beyond ideological partners.

2. Militarization and Nuclear Ambitions (Songun Policy)

Impact: The Songun ("military first") policy allocates vast state resources to defense, prioritizing nuclear weapons as a tool for regime survival and geopolitical leverage.

Relations: Nuclear and missile tests provoke condemnation and sanctions from the United Nations, United States, European Union, Japan, and South Korea.

Example: The 2017–2018 missile tests triggered intense global backlash, but summits with former U.S. President Donald Trump (2018–2019) briefly opened diplomatic channels. Talks ultimately failed due to North Korea's refusal to abandon its nuclear program.

3. Economic Dependence on China

Impact: Despite its ideological push for autonomy, North Korea remains heavily dependent on China, which accounts for around 90% of its trade.

Relations: China serves as a buffer against total isolation, providing food, fuel, and political cover. However, this asymmetry limits North Korea's autonomy and causes friction when China enforces UN sanctions.

Example: During 2017 Chinese sanctions enforcement, North Korea's economy suffered, prompting outreach to Russia and limited diplomatic overtures.

4. Sanctions and Economic Isolation

Impact: UN and bilateral sanctions targeting North Korea's nuclear and illicit activities exacerbate chronic inefficiencies in its command economy and block access to international markets, finance, and technology.

Relations: These sanctions entrench hostility with the West and regional powers, limiting diplomatic flexibility and deepening the regime's siege mentality.
Example: Since 2006, UN sanctions have restricted exports such as coal and textiles, prompting evasive tactics like ship-to-ship transfers and strained ties with enforcing nations.

5. Limited Marketization and Diplomatic Leverage
Impact: Informal markets (jangmadang) have grown under Kim Jong-un, offering economic relief but not translating into broader reform or openness.
Relations: North Korea's closed economy offers minimal incentive for foreign investment or cooperation. This diminishes its diplomatic leverage, especially in negotiations involving economic exchanges.
Example: Proposed projects during the 2018–2019 inter-Korean thaw, like the Kaesong Industrial Complex, collapsed when North Korea prioritized nuclear development over economic collaboration.

6. Illicit Economy and "Rogue" Status
Impact: To bypass sanctions and fund the regime, North Korea engages in illicit activities, including cybercrime, counterfeiting, and drug trafficking, reinforcing its pariah image.[137]
Relations: These activities provoke sanctions and deteriorate trust, especially with countries targeted by cyberattacks such as South Korea, Japan, and Bangladesh.
Example: The 2016 Bangladesh Bank cyberheist, linked to North Korean actors, prompted heightened scrutiny and restricted access to global financial systems.

Broader Implications:
Hostile Narrative: Domestic economic hardship, exacerbated by sanctions, feeds into the state's propaganda of a hostile external world, justifying isolation and militarization.

Selective Engagement: North Korea only engages diplomatically during economic crises, such as during famines or peak sanctions, but its rigid system prevents sustained cooperation (e.g., failed Six-Party Talks, 2003-2009).

Regional Instability: Provocations and dependency on China (and increasingly Russia) fuel instability in Northeast Asia, complicating efforts for regional security and economic integration.

2.2.1 Comparative Analysis
Contrasting the International Strategies of Germany and North Korea:
Germany embraces a multilateral, cooperative foreign policy rooted in democratic values, global integration, and rule-based diplomacy. As a central player in the European Union and active member of organizations such as the United Nations, NATO, and G7, Germany prioritizes diplomacy, trade, and global partnerships to advance mutual development and peace.
In stark contrast, North Korea's foreign strategy is shaped by isolationism, militarization, and strategic alliances based on self-preservation. Rooted in the Juche (self-reliance) and Songun (military-first) ideologies, its engagement with the global community is minimal and often confrontational, focusing on nuclear deterrence and reliance on a limited set of partners like China and Russia.
While Germany seeks regional stability and multilateral development, North Korea leverages nuclear capability and propaganda as tools for survival and geopolitical leverage, often escalating tensions in the Korean Peninsula and beyond.

[137] https://carnegieendowment.org/research/2024/10/cooperation-between-china-iran-north-korea-and-russia-current-and-potential-future-threats-to-america?lang=en
https://www.cfr.org/backgrounder/china-north-korea-relationship
https://www.eastwestcenter.org/publications/north-korea-germany-relations-ambassadors-perspective-diplomacy-pyongyang.

Comparative Assessment of Economic Outcomes in Both Countries:
Germany operates a highly developed, market-driven economy, ranked among the world's largest. Its economy is diversified, export-oriented, and innovation-driven, supported by strong institutions, education, and global trade networks. Germany is a leader in industries such as automotive, engineering, and green technology, with significant investments in digital transformation and sustainability.
North Korea, on the other hand, maintains a centrally planned, command economy marked by inefficiency, chronic shortages, and heavy military spending. While informal markets have grown and modernization policies like Byungjin have been introduced, economic progress remains limited due to international sanctions, lack of transparency, and isolation from global markets.

The stark economic disparity stems from Germany's openness and rule-based governance, compared to North Korea's rigid control, sanctions, and limited international cooperation. Germany benefits from global supply chains and EU integration, while North Korea relies on China for over 90% of its trade and resorts to illicit networks for revenue.[138]

Discussion on How Political Systems Contribute to These Outcomes
Germany's federal parliamentary democracy ensures transparency, political pluralism, and rule of law, which foster investor confidence, social stability, and efficient governance. Democratic institutions promote responsive policymaking, accountability, and economic adaptability.

North Korea's autocratic regime, led by the Kim dynasty, suppresses dissent and centralizes power. Political decisions prioritize regime survival over citizen welfare or economic reform. The absence of checks and balances enables policies like extreme militarization and repression, while deterring innovation and global integration.

Germany's democratic system thus nurtures sustainable development and robust international relations, while North Korea's authoritarian structure entrenches economic stagnation, isolation, and regional instability.

2.2.2 Conclusion: Summary of Key Findings
Germany and North Korea represent two fundamentally different models of statecraft, economy, and diplomacy. Germany's democratic, globally integrated system supports economic prosperity and strategic partnerships, while North Korea's autocratic, isolated model reinforces a cycle of economic hardship and hostile foreign relations.

The comparative analysis highlights how political ideology and governance shape each country's international standing and economic outcomes. Germany thrives on collaboration, institutional trust, and market liberalization, whereas North Korea leans on militarization, state control, and ideological rigidity.

Ultimately, the divergence in their international strategies, economic performance, and political institutions underscores the critical role of governance systems in shaping a nation's global footprint and domestic welfare.

2.2.3 Implications for Understanding of Governance Models on a Global Scale
Democracy vs. Autocracy in Global Context

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[138] https://www.international.gc.ca/country-pays/democratic_peoples_republic_korea-republique_populaire_democratique_coree/relations.aspx?lang=eng
https://www.uni-leipzig.de/en/newsdetail/artikel/neue-leipziger-autoritarismus-studie-erschienen-2022-11-09
https://www.idos-research.de/en/the-current-column/article/democracy-in-crisis-or-just-how-development-friendly-is-democracy/.

The case study of Germany and North Korea offers a clear illustration of how governance models shape national development trajectories, international behavior, and economic resilience. Democratic systems, as seen in Germany, prioritize accountability, institutional strength, and people-centered policy, enabling more stable and inclusive growth.
Autocratic systems, such as North Korea's, concentrate power in the hands of a ruling elite, often prioritizing regime security over socio-economic advancement. This model may allow for short-term control but lacks transparency, flexibility, and international legitimacy, often resulting in long-term isolation, stagnation, and humanitarian crises.

Impacts on International Relations and Global Governance
Democracies like Germany contribute to global governance structures, promoting multilateralism, collective security, and development aid. They are active in shaping global norms on climate action, human rights, and economic cooperation, strengthening the interconnectedness of the modern world.
In contrast, autocracies like North Korea often challenge the international rules-based order, using nuclear deterrence, cyber operations, and diplomatic brinkmanship to assert sovereignty and evade accountability. Their unpredictable behavior can disrupt regional stability and hinder coordinated global action.

Global Lessons on Governance
The comparison underscores the importance of institutional legitimacy, citizen participation, and rule of law in promoting peace, economic growth, and global collaboration.

While autocratic regimes may survive through control mechanisms and strategic alliances, their sustainability is often undermined by internal repression, lack of innovation, and limited diplomatic trust.

The broader implication is that inclusive, transparent governance not only strengthens national well-being but also contributes to a more stable and cooperative international system, whereas autocratic models often breed conflict, isolation, and economic fragility.

Investigating the truth-claim of the existence of free will

To what extent are the scientific arguments on the subject of "free will" convincing?

(Julius Lennart Pego)

1. Introduction

The paper depicts and evaluates two of the most compelling theories (and, consequently, arguments) in academic discourse regarding the topic of free will.[139] The theories differ in their conclusion as to whether free will exists and what conditions have to be fulfilled for its existence to be valid. Furthermore, the paper exclusively focuses on theories that affirm the existence of free will – compatibilism and event-causal libertarianism. As the discourse surrounding this topic is millennia old[140], it is impossible to examine all stated arguments since then in this short paper. Moreover, the paper does not cover every nuance of the chosen arguments, but instead focuses on the core statements of each theory. In spite of these concessions, the paper is still able to unveil the weaknesses of those theories and thus capable of drawing a conclusion – on the basis of the limitations.

1.1 Significance of the Topic

The prominent and sustained discourse already suggests that resolving questions regarding the nature of consciousness and its properties is of great interest to humankind – at the very least to vanquish our epistemological desires. However, the potential existence of free will carries implications that would influence ethical theories on a fundamental level.[141] As the objective of this paper differs from elaborating on the consequences that would arise from the subsequent paradigm shift in ethics, it will not discuss these in detail. That said, an adjusted understanding of ethical rationale would, for instance, change the perception of “criminals” and therefore alter the social procedures that are put in place for dealing with them. On this note, Pereboom articulates that a society influenced by the conclusion of hard incompatibilism – which denies the existence of free will – is favourable in comparison to other beliefs.[142]

1.2 Definitions and Clarifications

As a prerequisite, the paper needs to define and clarify certain terms that are essential for understanding the subject. In addition, to articulate arguments that are comprehensible to the reader, the paper has to state and clarify the moral framework that it employs.

1.2.1 Free Will

Philosophers utilize different definitions to describe what constitutes genuine free will. These subtle differences can shift the discourse to favour a specific argument and therefore disrupt any effort to debate on common ground. ***(i)*** The most prominent definition of free will is the

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[139] Libertarianism and compatibilism are the most prominently mentioned theories – apart from theological theories – in the “Free Will” entries of the Stanford Encyclopedia of Philosophy, the Internet Encyclopedia of Philosophy and the Routledge Encyclopedia of Philosophy.

[140] O’Connor, Timothy and Franklin, Christopher: Free Will, 2022, https://plato.stanford.edu/archives/win2022/entries/freewill/.

[141] Timpe, Kevin: Free Will, 2025, https://iep.utm.edu/freewill/.

[142] Caruso, Gregg: Skepticism About Moral Responsibility, 2021, https://plato.stanford.edu/archives/sum2021/entries/skepticism-moral-responsibility/.

freedom to do otherwise[143] – in the sense that the action, for example, is not determined beforehand. ***(ii)*** Some philosophers argue against this view, saying that for free will to exist it suffices if the agent is the source of the action.[144] To clarify this point, the agent – as in an existing instance of consciousness that can genuinely be called "I" – needs to be the root cause – the first cause – of the action. ***(iii)*** Morality is also often used to define free will, as most philosophers agree that it is intertwined with having free will.[145] This account seems self-evident and in no need of deeper analysis. If the person (the agent) is not fundamentally responsible for their actions, praise or blame cannot be attributed to said person – thus exonerating agents from moral responsibility.[146] ***(iv)*** To capture the essence of what constitutes free will, it is useful to clarify what it is not. The mere feeling of self-agency; counterfactual reasoning with the claim that one *could have* acted differently – in the sense that I theoretically had the ability to play the guitar instead of writing a paper, distinguished from my inability to fly; and the creation of different results (actions) all the while having the exact same initial conditions (physical and temporal); are all insufficient in this regard – I reiterate these points (with arguments) later in the main body. If free will exists, it has to be a mechanism which operates (in parts) outside of the causal chain and where the agent has fundamental control over the action made – in that the action is not a product of "luck".[147]

1.2.2 Determinism & Indeterminism

The concept of determinism dates – like free will – back thousands of years[148] and "many took [the truth-claim] to be strongly confirmed" with the introduction of Newtonian mechanics[149] – the precursor of what we now know as classical mechanics. The paper will employ the following definition of determinism:

> Determinism is true of the *world* if and only if, given a specified *way things are at a time t*, the way things go *thereafter* is *fixed* as a matter of *natural law.*[150]

Determinism is often directly linked to the existence – or rather the absence – of free will. But some philosophers do not agree with this supposed logical interconnection[151] – as the paper will discuss in the main body. Moreover, the truth-claim of determinism in itself is widely

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[143] O'Connor, Timothy and Franklin, Christopher: Free Will, 2022, https://plato.stanford.edu/archives/win2022/entries/freewill/.
[144] O'Connor, Timothy and Franklin, Christopher: Free Will, 2022, https://plato.stanford.edu/archives/win2022/entries/freewill/.
[145] O'Connor, Timothy and Franklin, Christopher: Free Will, 2022, https://plato.stanford.edu/archives/win2022/entries/freewill/.
[146] Caruso, Gregg: Skepticism About Moral Responsibility, 2021, https://plato.stanford.edu/archives/sum2021/entries/skepticism-moral-responsibility/.
[147] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.
[148] O'Connor, Timothy and Franklin, Christopher: Free Will, 2022, https://plato.stanford.edu/archives/win2022/entries/freewill/.
[149] O'Connor, Timothy and Franklin, Christopher: Free Will, 2022, https://plato.stanford.edu/archives/win2022/entries/freewill/.
[150] Hoefer, Carl: Causal Determinism, 2024, https://plato.stanford.edu/archives/sum2024/entries/determinism-causal/.
[151] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

disputed. Some arguments that question this alleged underlying structure are based on conclusions drawn from quantum mechanics. Even though not all interpretations of quantum mechanics predict an indeterministic reality – e.g. the Many-Worlds Interpretation[152] –, the most common ones do. These postulate that specific outcomes can solely be determined by probability – which undermines the property of determinism that the future is "*fixed*".[153]

1.2.3 Compatibilism & Incompatibilism

Theories concerning free will can mostly be distinguished into two categories. Compatibilists argue that the characteristics of determinism pose no threat to the potential existence of free will. Incompatibilists, on the other hand, diverge on this point. They see determinism as not reconcilable with the ability to exert genuine free will. Nonetheless, many theories in this category still claim that the existence of free will is possible. If reality is fundamentally indeterministic, the possession of free will is feasible, according to their reasoning.[154]

1.2.4 Ethical Framework: Utilitarianism

Moral theories that establish their moral judgement (only) on the basis of the consequences of an agent's action are considered consequentialist theories. For classical utilitarians pleasure and pain are the only intrinsic goods and bads that exist. These attributes therefore ought to be maximized – and minimized respectively – by acting accordingly. This criterion for judging actions is in the context of this paper in so far significant as it is not reliant on the state of the agent. The action can be deemed as good or bad – in relation to the consequences – even if the agent does not possess genuine responsibility for their action. In the same way as a toddler throwing stones at birds is not fundamentally responsible for their action but should nonetheless be stopped as the action minimizes (the so-called) utility. Of course, this theory is substantially more complicated than depicted but this outline is sufficient for all intents and purposes of this paper.[155]

2. Compatibilism

As compatibilists argue that determinism and free will are not at odds with each other, they need to logically prove how these properties are compatible. Especially as the freedom to do otherwise is often seen as a necessary requirement for moral responsibility and the existence of free will. This point is encapsulated in the "Principle of Alternative Possibilities" (PAP)[156], as well as the "Consequence Argument"[157]. To counter this seemingly self-evident fact, compatibilists constructed several arguments to invalidate the aforementioned conclusion.

2.1 Frankfurt-Style Cases

Harry Frankfurt created a type of argumentation which aims to undermine the notion that agents are only morally responsible if alternative possibilities (AP) exist.[158] As moral

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[152] Vaidman, Lev: Many-Worlds Interpretation of Quantum Mechanics, 2021, https://plato.stanford.edu/archives/fall2021/entries/qm-manyworlds/.
[153] Hoefer, Carl: Causal Determinism, 2024, https://plato.stanford.edu/archives/sum2024/entries/determinism-causal/.
[154] Timpe, Kevin: Free Will, 2025, https://iep.utm.edu/freewill/.
[155] Sinnott-Armstrong, Walter: Consequentialism, 2023, https://plato.stanford.edu/archives/win2023/entries/consequentialism/.
[156] Robb, David: Moral Responsibility and the Principle of Alternative Possibilities, 2023, https://plato.stanford.edu/archives/win2023/entries/alternative-possibilities/.
[157] Robb, David: Moral Responsibility and the Principle of Alternative Possibilities, 2023, https://plato.stanford.edu/archives/win2023/entries/alternative-possibilities/.
[158] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-

blameworthiness is mostly viewed as closely tied to the ability to exert free will, the argumentation – if logically sound – would therefore affirm the existence of free will. The thought experiment goes as follows:

1. J promised to do x.
2. As a precaution, K installs a microchip (M) in J's brain.
3. M can detect if J does x;
   If J does not do x, M activates and compels J to do x.

4.1 J does x.

4.2 J does not do x. M activates, which compels J to do x.[159]

Frankfurt draws the conclusion that in spite of the absence of AP – as both results are the same: A does x – it is still possible to attribute moral responsibility.[160] J is morally responsible for doing x in scenario 4.1 while J is exonerated of any responsibility in scenario 4.2. According to this reasoning the scenarios 4.1 and 4.2 are qualitative distinct.

If one utilizes a trivial understanding of moral responsibility and determinism, this analysis would hold. J acts in 4.1 out of their own will – without outside interference. J therefore fundamentally deserves praise or blame for doing x. But this conclusion is false. There exists no qualitative difference between the scenarios 4.1 and 4.2. The action is in both cases predetermined – as postulated by determinism. A mechanism which J cannot influence. The physical state of J's brain – as a *fixed* result of the past – dictates their behaviour. Thus, J is in neither case the source – the root cause – of the action and hence cannot be morally blamed or praised.[161]

But at the same time it is possible – and even beneficial – to distinguish between these scenarios. Suppose that "do x" means "inflict pain on someone". The actions the government (G) should pursue differ in each scenario. While G should remove M in both cases, the punishment for J should be more elaborate in scenario 4.1. What might sound counterintuitive – as J is not morally responsible for their actions – is perfectly consistent if G utilizes the same moral framework as this paper. The probability of J acting in the future in a way that would minimize the utility is higher in scenario 4.1, which justifies the adjusted punishment.

2.2 The Consequence Argument

Another angle to approach the problem of determinism in relation to free will is to attack the incompatibilist's conclusions of the Consequence Argument. The argument depicts a link between the past and the future, stating that a person does not have power over the facts of the future. The full (and simplified) argument can be formulated in the following way:

1. No one has power over the facts of the past and the laws of nature.

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xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

[159] Own structure of the thought experiment.

[160] Timpe, Kevin: Free Will, 2025, https://iep.utm.edu/freewill/.

[161] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

2. No one has power over the fact that the facts of the past and the laws of nature entail every fact of the future (i.e., determinism is true).
3. Therefore, no one has power over the facts of the future.[162]

One avenue to render the conclusion – that free will is incompatible if the argument is consistent – as false, is to utilize a different interpretation of the word "power". Instead of "power", one can use "ability" as a synonym, which would alter the first statement as follows:

1. No one has the ability to perform some action that would cause the facts of the past or the laws of nature to be different.[163]

Compatibalists continue to argue that the word "ability" also entails a hypothetical ability to do something. Hence, if an action of the past seemed feasible – as in not fundamentally at odds with common sense – the person had the ability to take the action – even if not actualised. For example, J had the ability to play guitar even though J had not done so – in contrast to J's inability to fly. This interpretation of "ability" is called "broad ability" and is distinct from incompatibilst's interpretation labelled "causal ability".

Broad Ability:	S is broadly able at *t* to bring about p if there is a course of action K such that at *t* (1) S is able to do K, and (2) were S to do K then p.
Causal Ability:	S is causally able at *t* to bring about p if there is a course of action K such that at *t* (1) S is able to do K, and (2) S's doing K would make it the case that p. [164]

Applying the broad interpretation of ability to the first statement of the consequence argument creates a contradiction. Under this interpretation, everyone would have the ability to perform various actions that would cause the facts of the past to be different. In the sense that J had the ability to play guitar at *t*, which would have changed the facts of the past (as J did not actually play guitar at *t*).[165]

While the deduction with this premise is correct, it misses the point of the discourse. This line of argumentation makes no contribution to evaluating if free will exists. Possessing a

[162] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.
[163] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.
[164] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.
[165] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

hypothetical ability that is impossible to actualize does not endow us with free will. In addition, broad ability tries to differentiate between two actions. One action (y) is hypothetically possible, whereas the other (z) is not. J had the ability to play guitar (y), but did not have the ability to fly (z). However, this distinction is highly implausible. Assuming determinism is true, both actions are equally impossible. Compatibilists – in constructing this argument – appeal to the intuition that y appears more tangible. But this is a fallacy. Either action would entail breaching the laws of nature – as doing y at *t*, when one in reality did not do y at *t*, is inconsistent with determinism – and thus is impossible in the same sense.[166]

2. Event-Causal Libertarianism

Libertarians diverge from compatibilists in their belief that determinism is not reconcilable with the concept of free will. Exerting free will is only possible if alternative possibilities (AP) exist, according to libertarians. For AP to hold true, the underlying structure of reality needs to be indeterministic. Libertarians are not unified with regards to how AP specifically facilitates free will. This paper will solely discuss arguments brought forth by event-causal libertarians. They claim that agent actions are a result of indeterministic events and thus can be considered free.[167]

3.1 The Luck Objection, the Basic Argument & Ultimate Responsibility

Robert Kane is thereby one of the most prominent figures of this direction of thought.[168] His line of argumentation tries to circumvent the most common raised objections. Two of which are referred to as the Luck Objection and the Basic Argument. ***(i)*** The former illustrates that even if an agent has genuine AP as a result of indeterminacy the agent still cannot exert free will as they lack any meaningful control other than the mechanism which brought about the action. To clarify, J possesses true AP with regards to if J plays guitar at *t* – if indeterminacy is true. But the actualized outcome is fundamentally based on luck (or probability).[169] ***(ii)*** The latter alludes to the problem of infinite regress that arises with a particular line of reasoning. For to be able to hold an agent morally accountable, the action itself does not have to be a direct consequence of indeterminate events, some libertarians allege. It suffices if the action is caused by the Current Established Psychology (CEP) – the current character (mental state) of the agent – which in turn was formed by indeterminate events in the past (*t**). But this just pushes the problem of agent causation – necessary for moral accountability – to an earlier point in time. As actions based on indeterminate events do not qualify for genuine agent causation the first cause (cause of oneself) – establishing fundamental moral accountability –

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[166] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

[167] Clarke, Randolph and Capes, Justin and Swenson, Philip: Incompatibilist (Nondeterministic) Theories of Free Will, 2021, https://plato.stanford.edu/archives/fall2021/entries/incompatibilism-theories/.

[168] Michaelides, Samuel: Is Libertarian Free Will an Inescapably Incoherent Concept?, 2024, https://uhra.herts.ac.uk/bitstream/handle/2299/28181/18011475%20MICHAELIDES%20Samuel%20Final%20Version%20of%20PhD%20Submission.pdf?sequence=1&isAllowed=y.

[169] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

needs to occur before *t**. This leads to an infinite regress, as no prior action can satisfy this condition.[170]

Kane, in constructing his argument, asserts that Ultimate Responsibility (UR) does not automatically follow from the existence of AP. UR is of greater importance to the free will-discourse than PAP is because "PAP might be necessary for free will but it is not sufficient for free will"[171]. This distinction is portrayed by the so-called Austin-style examples:

1. J wants to do *x*.
2. J is principally able to do *x* as they have done *x* consistently in the past.
3. J fails to do *x* because of a bodily function caused by an indeterminate event.

To allege that J is UR for failing *x* – as the action was not determined – is an unreasonable assertion. Kane concludes that UR must therefore be based upon a more rigorous foundation.

3.2 Self-Forming Actions, Plural Voluntary Control & Parallel Processing

(A) Self-forming actions (SFA) are in his view the key to possessing UR for one's actions. He postulates that SFA occur in situations of a perceived dilemma – e.g. moral choices.[172] The outcome of SFAs are non-deterministic and do not rely on the agent's CEP – thus being a closed system. Consequently, the SFAs, according to Kane, are "regress stopping" (in reference to the Basic Argument).[173]

(B) Moreover, he addresses some counterarguments by formulating ten conditions that need to be met in order for an SFA to genuinely come about. The ability for plural voluntary control – as it is called – is defined as follows:

(1) An ability to
(2) bring about
(3) at a specific time
(4) whichever of the options they will or want,
(5) for the reasons they will to do so,
(6) on purpose or intentionally rather than accidentally, by mistake or merely by chance (as when by mistake I press the wrong button), hence
(7) voluntarily (in accordance with their wills rather than against them),

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[170] Michaelides, Samuel: Is Libertarian Free Will an Inescapably Incoherent Concept?, 2024, https://uhra.herts.ac.uk/bitstream/handle/2299/28181/18011475%20MICHAELIDES%20Samuel%20Final%20Version%20of%20PhD%20Submission.pdf?sequence=1&isAllowed=y.
[171] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.
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(8) as a result of their efforts, if effort should be required,

(9) without being coerced or compelled, or

(10) otherwise controlled or forced to choose one way or the other by some other agent or mechanism.[174]

Condition (6), for instance, directly addresses the Luck Objection. If an SFA is done on purpose or intentionally, the resulting action cannot be said to be a product of luck, according to the reasoning.[175]

(C) In addition, the indeterministic process of SFAs needs to be exemplified – illustrating how indeterminacy can lead to UR. (4), (5), (7), and (8) suggest that SFAs are an active endeavour of the agent's will. This pursuit of the will to resolve the dilemma is central, as it is the mechanism to attribute UR to the agent (in contrast to outside conditions). In order to meet the requirement for possessing UR, the agent has to will the competing actions – that would resolve the dilemma – simultaneously (up to the point where one outweighs the other, that is). Otherwise, the SFA would be prone to, what Kane refers to as one-way rationality.[176] If the will is already set on a specific outcome (*g*) it is in a sense determined. Even if the outcome is *not-g* – as a result of indeterminate events in the brain – it is not reasonable to attribute UR to the agent, inasmuch as *not-g* was not the intended outcome of the agent's will.[177] Kane therefore depicts how the simultaneous willing of competing actions (what he calls parallel processing) functions: During SFAs, the agent's will is split, and the consequent instances simultaneously compete to resolve the dilemma. The will is thereby represented by neural networks in the brain. If one of these "networks reaches a certain activation threshold"[178], the corresponding action is initiated by the agent. This process is indeterministic as a result of the "tension-creating conflict in the will".[179]

Thus, if an agent performs an SFA – with the specific conditions in mind – they hold UR for the action, Kane argues. Moreover, the agent even holds UR for actions that don't fit the criteria of an SFA but that are influenced by their CEP, which in turn is an accumulated result of past SFAs.[180]

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[174] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

[175] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/3148390/no.ntnu%3ainspera%3a192806794%3a98442262.pdf?sequence=1&isAllowed=y.

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[177] Michaelides, Samuel: Is Libertarian Free Will an Inescapably Incoherent Concept?, 2024, https://uhra.herts.ac.uk/bitstream/handle/2299/28181/18011475%20MICHAELIDES%20Samuel%20Final%20Version%20of%20PhD%20Submission.pdf?sequence=1&isAllowed=y.

[178] Michaelides, Samuel: Is Libertarian Free Will an Inescapably Incoherent Concept?, 2024, https://uhra.herts.ac.uk/bitstream/handle/2299/28181/18011475%20MICHAELIDES%20Samuel%20Final%20Version%20of%20PhD%20Submission.pdf?sequence=1&isAllowed=y.

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[180] Partanen, Kassu Ian Kasperi: On Free Will and Moral Responsibility. A Defense of Hard Incompatibilism, 2024, https://ntnuopen.ntnu.no/ntnu-

3.3 Evaluation of Kane's Theory

With his theory, Robert Kane tries to properly address – as mentioned above – the various problems libertarians face. ***(i)*** He seems to circumvent the problem that is brought forth by the Basic Argument as SFAs are theoretically independent and don't rely on the CEP. But solely claiming that SFAs have the ability to be "regress stopping" in this way does not suffice. To find a counterargument to this point, one just has to question the mechanism behind the competing wills during an SFA. What constitutes the formation of those exact competing wills? One could imagine countless competing wills for every imaginable dilemma. Instead of J willing *g* and *not-g*, they could hypothetically be willing *f* and *not-f*. This prior filtering of the will can only be explained by the CEP influencing the SFA.[181] ***(ii)*** Additionally, Kane's reasoning to avoid the Luck Objection is opaque at best. Again, it does not suffice to merely claim that SFAs are not fundamentally dependent on luck – but instead are willed with purpose or intention (6). Even if one accepts the mechanism behind parallel processing to be true, what conclusively determines that one neural network reaches the threshold (and thereby is faster than the other)? Kane counters by distinguishing between Austin-style examples and SFAs. To him, only the former action can be considered influenced by luck, as the agent was not actively intending for this outcome to happen. This is but an argument based on semantics. It is not important how the phenomenon is labelled. The agent has no direct control over the outcome of the SFA and therefore cannot be said to possess UR over their action.[182]

4. Conclusion

The paper has outlined some of the most common arguments in scientific discourse with regard to free will. Compatibilism and (event-causal) libertarianism alike aim to validate the existence of free will – while operating under different assumptions concerning determinism. The motivation for this goal is often derived from the believed interconnection between free will and the ability to establish moral theories. As the paper has stated before, this depicted link is not convincing – on the contrary, moral theories can indeed benefit from an invalidation of free will.

The thorough rejections of the illustrated arguments obviously do not prove the non-existence of free will, however, they establish a basis for an informed sceptical view in relation to the existence of free will – especially as the depicted arguments are firmly anchored in contemporary discourse.

In conclusion, it is pivotal to investigate this metaphysical question in further detail, as the truth-claim carries far-reaching implications for how societies and moral theories should be organized and constructed.

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NACHWORT

Mit dem Abschluss des Studienzeiten-durchgangs 2024/2025 neigt sich eine spannende und bereichernde Phase dem Ende zu. Die vergangenen Monate waren geprägt von einer großen Neugier auf die jeweils gewählten Themen sowie von einem intensiven fachlichen Austausch untereinander. Es war eine Zeit des Lernens, des Entdeckens und des gemeinsamen Wachstums. Die hier präsentierten Facharbeiten spiegeln nicht nur die vielfältigen Interessen und engagierten Bemühungen des Studienzeitendurchgangs wider, sondern auch den intensiven Lernprozess, den alle Teilnehmenden durchlaufen haben.

Vielen Dank an all diejenigen, die die Studienzeiten ermöglicht haben, namentlich Holger Wendebourg (Förderkoordinator), Noëlle Nowack (Dozentin) sowie den Verfasserinnen und Verfassern der Facharbeiten Kim Berg, Nils Habben, Jonn Horstmann, Talika Kolboom, Enock Ofosuhene und Julius Lennart Pego.

Wir hoffen sehr, dass Sie und Ihr beim Lesen der Facharbeiten ebenso viel Freude und Inspiration gefunden haben wie wir während des Schreibens. Mögen die Themen zum Nachdenken anregen und neue Perspektiven eröffnen!